Introduction to Software Engineering (ISAD1000)

# Lecture 4: Version Control

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Discipline of Computing
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# Outline

# Version Control

- Almost every software project uses *version control*.
  - The ones that don't. . . *should!*
- It's a way of tracking:
  - A complete history of all work done so far.
  - Multiple simultaneous versions of the product.
- To help us, we need a *version control system* (VCS).
  - The most well-known one is probably "Git".
  - Others include "Mercurial", "Subversion", "Perforce", and many more.
  - We cannot realistically do version control without a VCS.
- But it's not all automated. The VCS is a tool, and we must learn how to use its powers for good.

# Git is not Github

- The VCS (Git, Mercurial, etc.) is just a piece of software.
  - You download and install it on your computer.
- You may know of websites like GitHub.com, Bitbucket.org, or others.
  - These are *services* that happen to use Git, Mercurial, etc.
  - They provide a central place to store ("host") your project code.
  - They also provide features to help your team track its progress, discuss issues, and conduct code reviews.
- The VCS and the hosting service are separate things.
- You can use the VCS *by itself* (just on your own computer), or in conjunction with a hosting service.

# Undoing Mistakes

- At some point, you may experience the following:
  1. It works!
  2. Now I'll just add the next feature...
  3. Damn. Now it's broken.
  4. Argh! Now I can't figure out how to get back to the original version.
  5. Start again from scratch.
- The easy solution is to *save a copy* before making drastic changes.
- But this leads to another problem:
  - After a while, I have directories called "new", "original", "working", "working.3", "old", "new/old", "old/old/new", etc.
  - Each one is a particular version, and they build up over time.
  - But I *can't remember* what is what.

# But text editors can undo changes...

- Any remotely reasonable text editor has an "undo" feature.
- But this isn't good enough! A few reasons:

1. You often want *both* the old and new versions.
   - Don't throw away the new version just because it's broken.
   - You may yet figure out how to fix it!
2. The editor's "undo buffer" is only temporary (in general).
   - Editors forget all the undo information when you close them.
3. There's still too much for *you* to remember.
   - Since the last working version, you may have inserted/deleted hundreds of words across several files.
   - Will you remember how much you need to undo in each file?
   - Will you even remember *which files* you've modified?

# How does a VCS help?

- For every update ("commit") made to a software project, the VCS records:
  - What was changed.
  - The date and time.
  - The person responsible (since you're probably working in a team).
  - A description entered by that person.
- You can tell the VCS to:
  - Show the list of commits in order.
  - Retrieve the code as it existed at a specific time in the past.
  - Show the exact differences between the code at two different times.
- All you have to do is: tell the VCS whenever you make a change (a "commit"), and enter a description.
- Now, you can safely make any changes you like, and always have the ability to undo them later on.

# Repositories

- A *repository* ("repo") stores the complete project (all its versions).
- Older VCSs had a single "centralised" repository.
  - Stored on a central server.
  - Each team member can "check out" a few files, like borrowing books from a library.
  - Later they "check in" the updates they've made.
  - Nobody else can modify the same files at the same time.
- Newer VCSs (e.g. Git and Mercurial) are "distributed".
  - Each team member has their own "local" repository.
  - Typically there's *also* a central repository.
    - Often hosted on GitHub.com, Bitbucket.org, etc.
  - The different repositories are periodically kept in sync with each other.
    - People *can* update the same files at the same time.
    - Intelligent algorithms help "merge" their updates together.

# Local Repository vs. Working Directory

- Your "working directory" stores the version of the code that you're currently working on.
  - *Probably* the latest version (but see later discussion on branches).
  - This is just straightforward, ordinary directory.
- Your local repository stores all versions of the code (except any *uncommitted* changes in the working directory).
  - Typically the repo is stored in a sub-directory in the working directory ("`.git/`" for Git, "`.hg/`" for Mercurial, etc.).
  - VCS-specific format – not directly human-understandable.
- The VCS knows how to (among other things):
  - Save the working directory (or parts of it) into the repository.
  - Load a particular version from the repository into the working directory.

# Git

- Created by Linus Torvalds, to help manage the Linux OS kernel (which he also initially created):
  - The Linux kernel is a vast project: 22 million lines of code, 4,600 new lines added *per day*, over 13,500 developers, and running since 1991 [1].
  - This is what Git was created to handle.
- We'll use Git via the command-line.
  - There are lots of GUI and web tools available too.
  - But the command-line is better for learning.
- Git has a whole suite of little commands:

```
[user@pc]$ git add ...
```

```
[user@pc]$ git commit ...
```

```
[user@pc]$ git reset ...
```

[1] https://www.linux.com/infographic/25-years-linux-kernel-development

# Git – Setting Up a Local Repository

- Before you use Git for anything, set up your identity:

```
[user@pc]$ git config -global user.name "Your Name"
```

```
[user@pc]$ git config -global user.email "me@xyz.com"
```

  - This will help identify your work in the repository (since there could be other people involved too).
  - "-global" applies this to *all* projects (for this login account).
- To actually create a repository for a project:

```
[user@pc]$ mkdir myproject
```

```
[user@pc]$ cd myproject
```

```
[user@pc]$ git init
```

This will create and populate the `.git` directory (hidden, due to the starting dot).

# Basic Git Usage – Staging and Committing

1. Create/modify some .java files in your project.
2. Tell Git to *stage* the updates (to prepare for a commit):

```
[user@pc]$ git add MyCode.java MyOtherCode.java
```

```
[user@pc]$ git add YetMoreCode.java
```

3. Tell Git to *commit* the staged files:

```
[user@pc]$ git commit -m "Fixed input validation bug."
```

   - Always provide a meaningful description of what you did.

To list files that are (1) staged, (2) new/modified since the last commit but not staged, or (3) unchanged:

```
[user@pc]$ git status
```

To see all un-staged code changes in detail:

```
[user@pc]$ git diff
```

# More Notes on Staging and Committing

- A commit should represent "one thing" – one bug fix, one small feature, etc.
  - If you make two distinct changes, make two separate commits.
  - Makes it easier for others (and yourself in the future) to see what you did.
- Files can be un-staged, prior to a commit:

```
[user@pc]$ git reset MyCode.java
```

```
[user@pc]$ git reset
```

- If you mess up a commit, fix it by making *another* commit.
  - The thing about the ultimate "undo" tool. . . is that it has to remember everything you do, including the stupid things![2]

[2] There are ways of changing already-made commits, but this is risky, and can defeat the purpose of version control. In ISE, we'll assume commits are irrevocable.

# Logs and Diffs – Viewing Past Work

- To get a summary of all commits:

```
[user@pc]$ git log -graph
```

  - ("-graph" is optional, but useful when we get to branching.)
- To see the entire history of a particular file:

```
[user@pc]$ git log -p MyCode.java
```

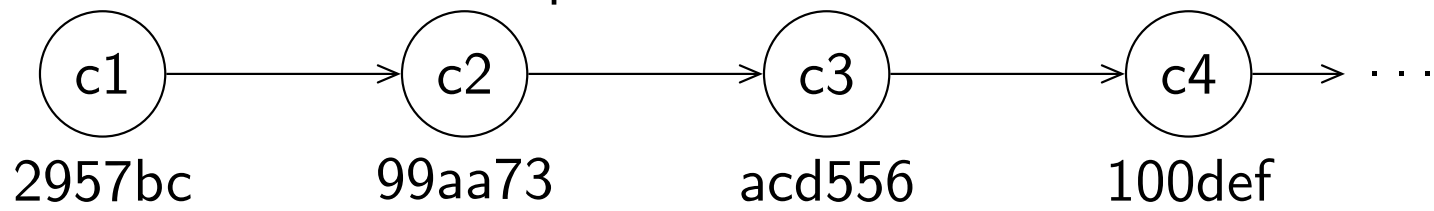
  - "+" marks a line that was added.
  - "−" marks a line that was deleted.
  - "@@" identifies the location of changed lines (though you can usually tell anyway).
- To see the differences between two commits (across all files):

```
[user@pc]$ git diff 46b9bc 5f14b6
```

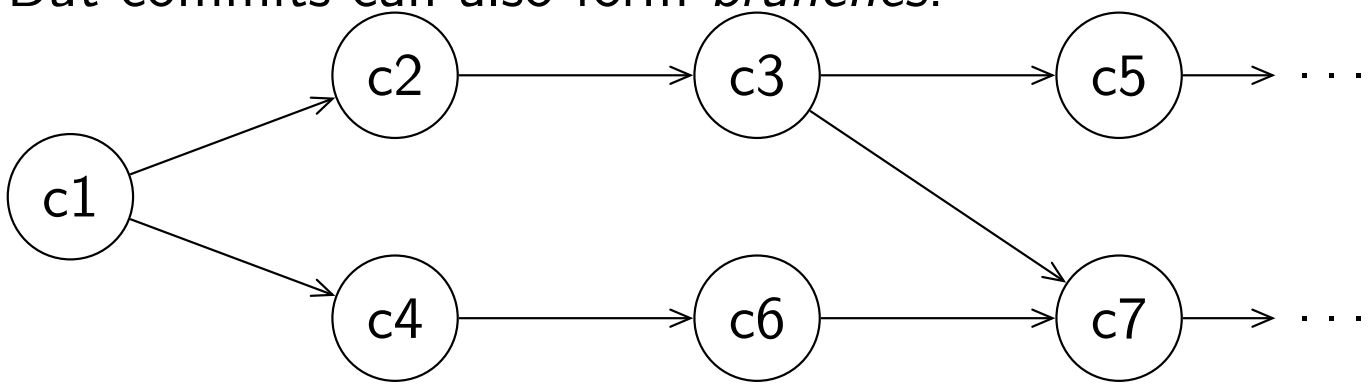
  - Each commit is identified by a "hash" code (shown by `git log`).
  - 40-chars long, but you can abbreviate them.

# Branches

- You can think of a sequence of commits like this:




  - 4 commits in a row, each based on the previous one.
- But commits can also form *branches*:




  - We have two branches, originating from c1.
  - Each branch has several commits, until they are merged at c7.

# Branching – Why?

- Branching allows *multiple simultaneous versions*.
- In a simple case, you have:
  - A "master" branch for the main "it-works!" version.
  - One or more "feature" branches for whatever crazy experimental stuff you're adding/fixing.
- In a team, different developers work on different feature branches.
- Branching is vital because you need easy access to these different versions.
  - People will ask you for the latest working version, so they can actually use it.
  - But you can still make experimental changes without risking (a) what you're already done, and (b) what everyone else is working on.

# Branching in Git (1)

- By default, you have one branch called "master".
- To make a new branch, based on the last commit in the current branch:

```
[user@pc]$ git branch mynewbranch
```

- To switch branches:

```
[user@pc]$ git checkout mynewbranch
```

  - You must commit any uncommitted changes first.
  - This will *delete and replace* your code with the latest version in "mynewbranch".
  - "`git checkout -b mynewbranch`" will both create and checkout a new branch.
- Now, your next commit will be in the new branch.
  - Switch back to "master", and you'll see the old version.

# Branching in Git (2)

- To list the existing branches, and see which one is current:

```
[user@pc]$ git branch
```

  - "`git status`" will also show the current branch name.

- You can create a new branch based on *any* commit:

```
[user@pc]$ git branch mynewbranch ff823e
```

  - If you made a big mistake in an existing commit, you can create a branch based on the *previous* commit, and "try again".

- You can rename branches:

```
[user@pc]$ git branch -m mynewbranch featurexyz
```

(Renames "mynewbranch" to "featurexyz".)

- You can also delete branches, but that's associated with *merging*.

# Merging

- Branching would be useless without later being able *merge* branches together.
  - Feature branches are where most work is done.
  - But this work must end up in the "master" branch somehow.
- "`git merge`" merges another branch into the current one:

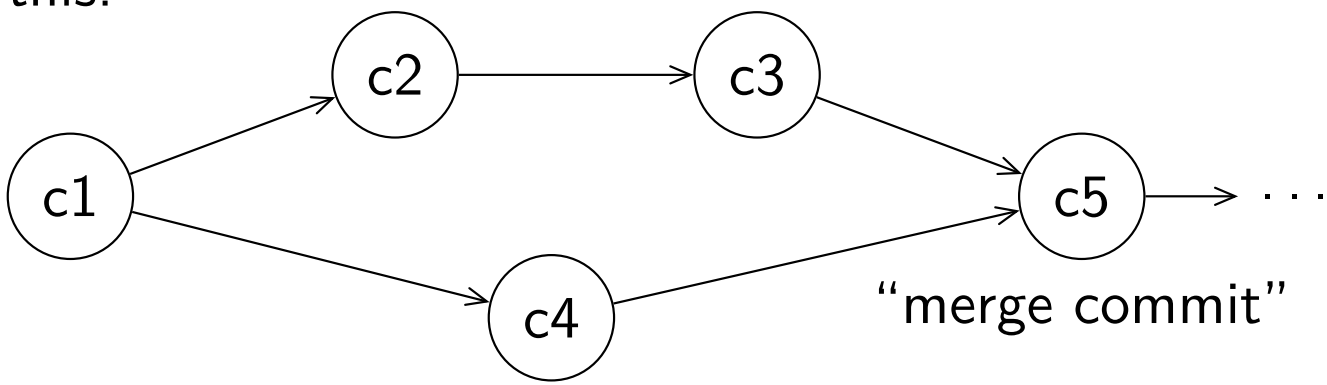
```
[user@pc]$ git checkout master
```

```
[user@pc]$ git merge mynewbranch
```

- Here we merge "mynewbranch" into "master" (in Git):
  - We're finished with mynewbranch.
  - All our work is now in "master" (until we make another new branch).
- Merging creates a special "merge commit": a mixture of the last commits in "master" and "mynewbranch".

# Merging – WTF?

- How does Git *know* how to merge things?
- Merging seems like can't possibly be automated. Consider this:




  - These branches *both* have commits, which could be anything!
  - We're asking Git to combine two different pieces of code and make a workable result!
  - This ought to be a *hard* problem!

# Merging – How it Works

- Git can't *always* merge things automatically, but often it can.
- First, it finds the "common ancestor": the point where the branches first separated.
- Second, Git executes the "diff3" algorithm. This tells it:
  - What has changed in each branch since the common ancestor.
  - What has stayed the same in each branch.
- Often the two branches change *different sections of code*.
  - Git will automatically commit these changes.
- If the two branches both change the *same section of code*, this is a "merge conflict".
  - Merge conflicts must be resolved manually.

# Merge Conflicts and Manual Merging

- A "`git merge`" may report something like this:

```
CONFLICT (content): Merge conflict in Xyz.java
```

  - Both branches have changed the *same parts* of Xyz.java.
  - Git couldn't work out how to merge both changes.
- Git will leave both changes in Xyz.java, with notes on which branch each one comes from.
- You must:
  1. Edit Xyz.java, see both changes, and figure out for yourself how to reconcile them.
  2. Stage and commit your new changes:

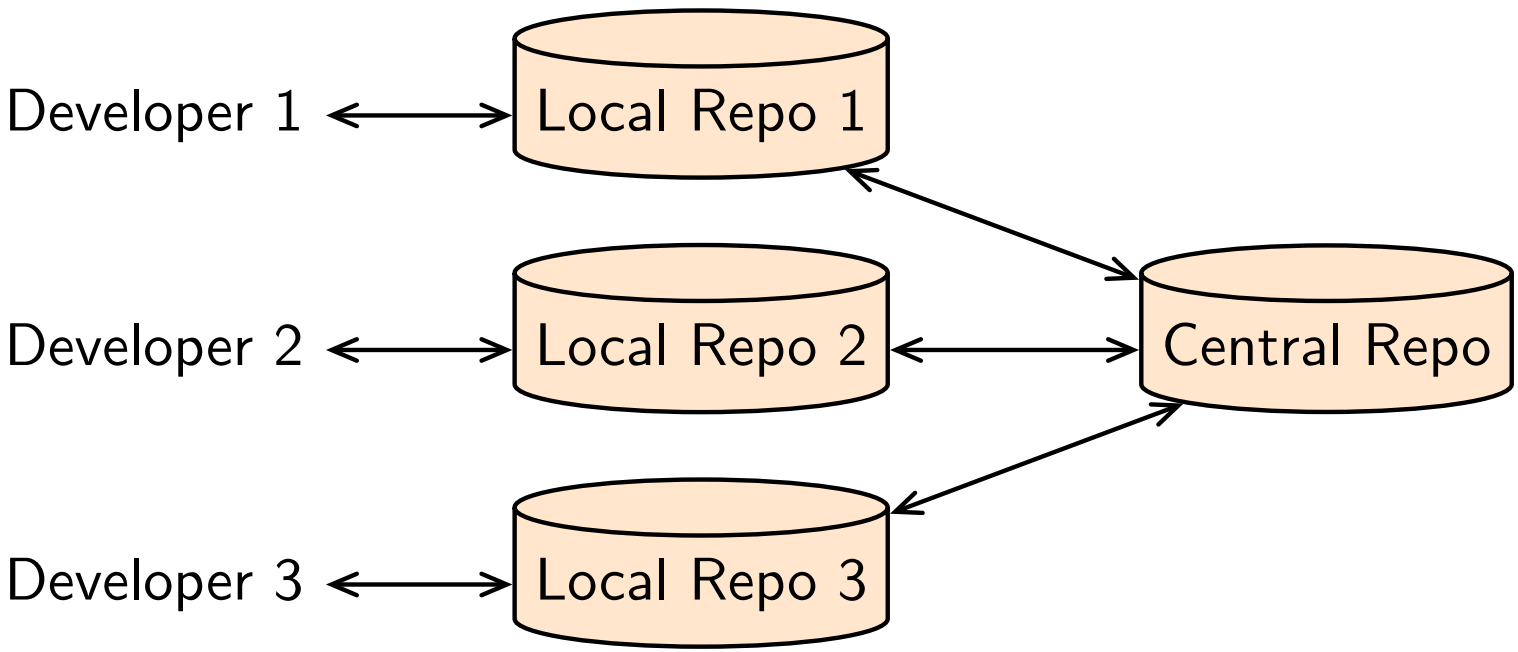
```
[user@pc]$ git add Xyz.java
```

```
[user@pc]$ git commit -m "Merged abc-xyz changes."
```

- (nb. "`git status`" also shows what file(s) need attention.)

# Multiple Repositories

- Recap: you typically use *multiple* repos (in a distributed VCS).
- Typically:
  - Each developer has a "local" repo. This is what we've been working with so far.
  - There's also a central repo.



# Multiple Repositories – Why?

One repo keeps track of everything. So why *more* than one?

1. Safety.
   - With a centralised VCS, if the repo gets corrupted/deleted, you could lose everything!
   - Distributed version control is a natural backup system.
2. Reliability. If/when the central server goes down, then:
   - With a distributed VCS (e.g. Git) you still have a local repo.
   - With a centralised VCS, nobody can do any work – massive lost productivity.
3. Performance. For large teams and large projects:
   - A centralised VCS can get swamped, both by CPU intensive tasks and network traffic.
   - A distributed VCS doesn't need the network most of the time, and spreads around the CPU load. Team size is irrelevant to performance, because each developer uses their own PC.

# Remote Repositories in Git

- Each repository keeps track of "remotes".
  - Typically there's a remote called "origin" – the central repo.
  - Git is flexible, though:
    - You could have *no* central repo at all, and instead sync up with other team members' local repos directly.
    - You could have several central repos in a complicated hierarchy.
- The central repo (if it exists) is mostly for coordination:
  - Removes any doubt as to *who* has the latest version.
  - Minimises the amount of syncing needed – you only need to keep your local repo in sync with *one* other (typically).

# Cloning

- Cloning *creates* a new repository based on an existing one.
- Also sets up the original repository as the "origin" (a remote repo) for the new one.
- Typically used to create a new local repo based on an existing central repo:

```
[user@pc]$ git clone https://xyz.com/myproject.git
```

  - This assumes we have an existing (central) repo on xyz.com.
- We can also create a 2nd local repo:

```
[user@pc]$ git clone myproject myproject2
```

```
[user@pc]$ cd myproject2
```

  - Assumes we're one level up from the `myproject/` directory.
  - One local repo should really be "bare" – see the prac worksheet.

# Pushing and Fetching

- You can *push* and *fetch* to keep different repos in sync.
  - Typically done on *one branch* at a time.
  - Copies any commits not already copied.
- **Pushing TO a repote repo:**
  - Upload "mynewbranch" to "origin" (and make "origin" the current remote):

```
[user@pc]$ git push -u origin mynewbranch
```

  - Upload the *current* branch to *current* remote:

```
[user@pc]$ git push
```

- **Fetching FROM a remote repo:**
  - Get "master" from "origin":

```
[user@pc]$ git fetch origin master
```

  - Get *everything* from the *current* remote:

```
[user@pc]$ git fetch
```

# Don't Panic

- Can push and fetch overwrite things?
- What if multiple developers push changes at the same time?
- You don't have to worry!
  - Each commit is considered "immutable" (unchangeable).
  - Therefore, anything "pushed" or "fetched" must in the form of *new* commits.
  - New commits never overwrite existing ones – they're just added.

# Working as a Team

Git can be used in different ways, but here's a reasonable scenario:

1. The central repo contains a "master" branch.
2. Developer 1 wants to work on a new feature:
   - 2.1 *Fetches* the master branch (so the local repo is up-to-date).
   - 2.2 Creates a new "featureX" branch in their local repo.
   - 2.3 Gets featureX working, making some commits.
   - 2.4 *Pushes* featureX (the whole branch) to the central repo.
3. Developer 2 performs a code review:
   - 3.1 *Fetches* featureX from the central repo.
   - 3.2 Inspects the code.
   - 3.3 If anything is wrong, we repeat from step 2.3.
4. On the central repo, the team now *merges* featureX into master.
5. All developers *fetch* master from the central repo (so as to be up-to-date).

# That's all for now!