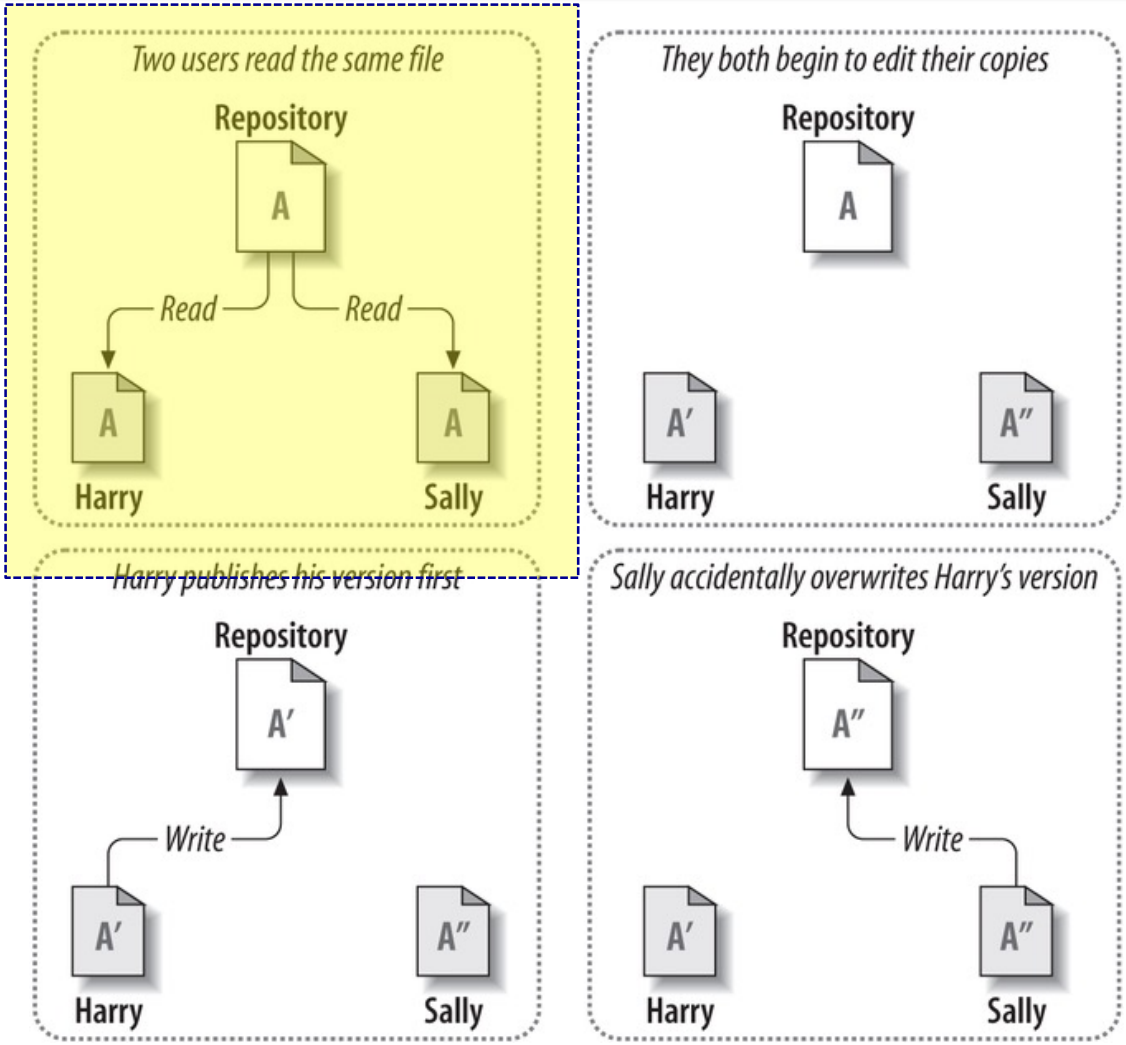
Introduction to Version Control

- Source-code control: motivation
- Basic Concepts: Repository
- Basic Concepts: Working Copy
- Intro to git
- Some git workflow
- The "commit" concept
- Pushing, pulling, fetching and merging
- Conflict resolution

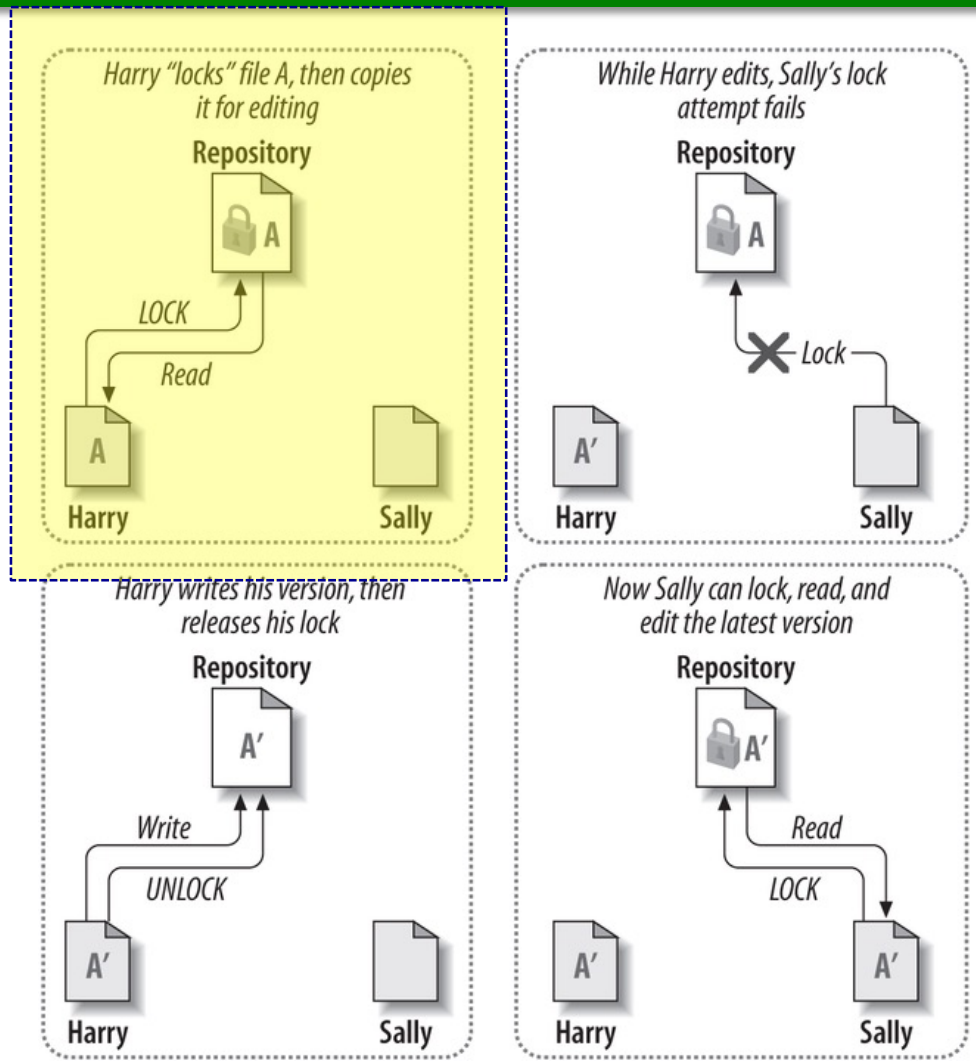
Basic Concepts: Repository

- A repository remembers every **committed** change to every **controlled** file
  - Even remembers additions and deletions to directory trees
- Clients reading from the repository normally sees latest version of file structure
  - Clients, however, can also choose to view previous states of the file structure
- Examples of previous states:
  - "What did this directory contain last Wednesday?"
  - "Who was the last person to change this file?"
  - "What changes did Pat make to this file?"
  - "Give me the version for release 3 of the code."

What we do not expect/want…



One approach around problem…

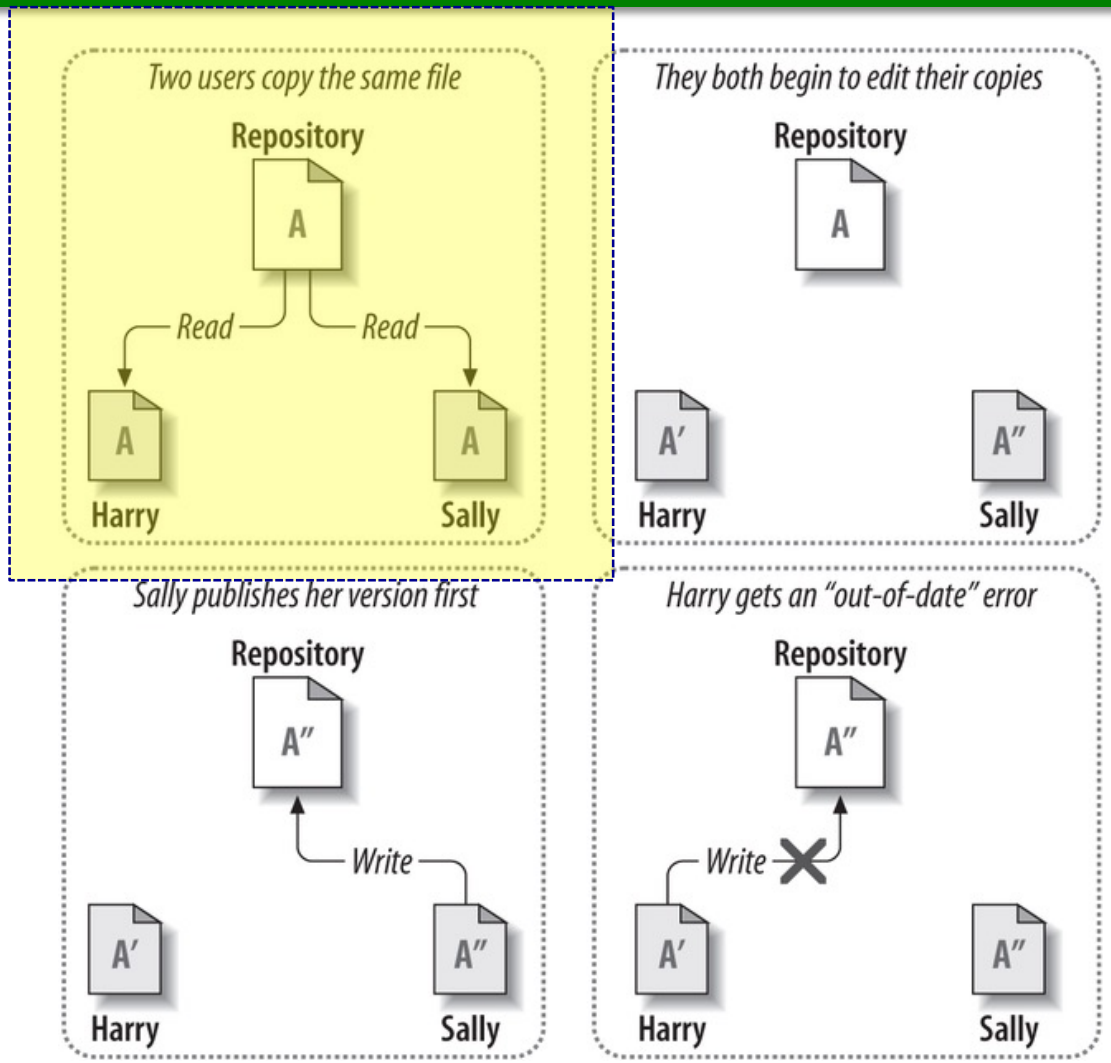


Some downsides to "locking"

- Can cause some administration problems
  - User with lock on holidays? sick?
  - Is it appropriate for all changes?
- Awkward in distributed environments
  - **Presence** of locking is **unattractive** for open-source projects
  - Such projects have developers located around the globe
  - Locked files would be very inconvenient (if not disastrous)
- Locking gives a false sense of security.
- But how do we manage without locking?

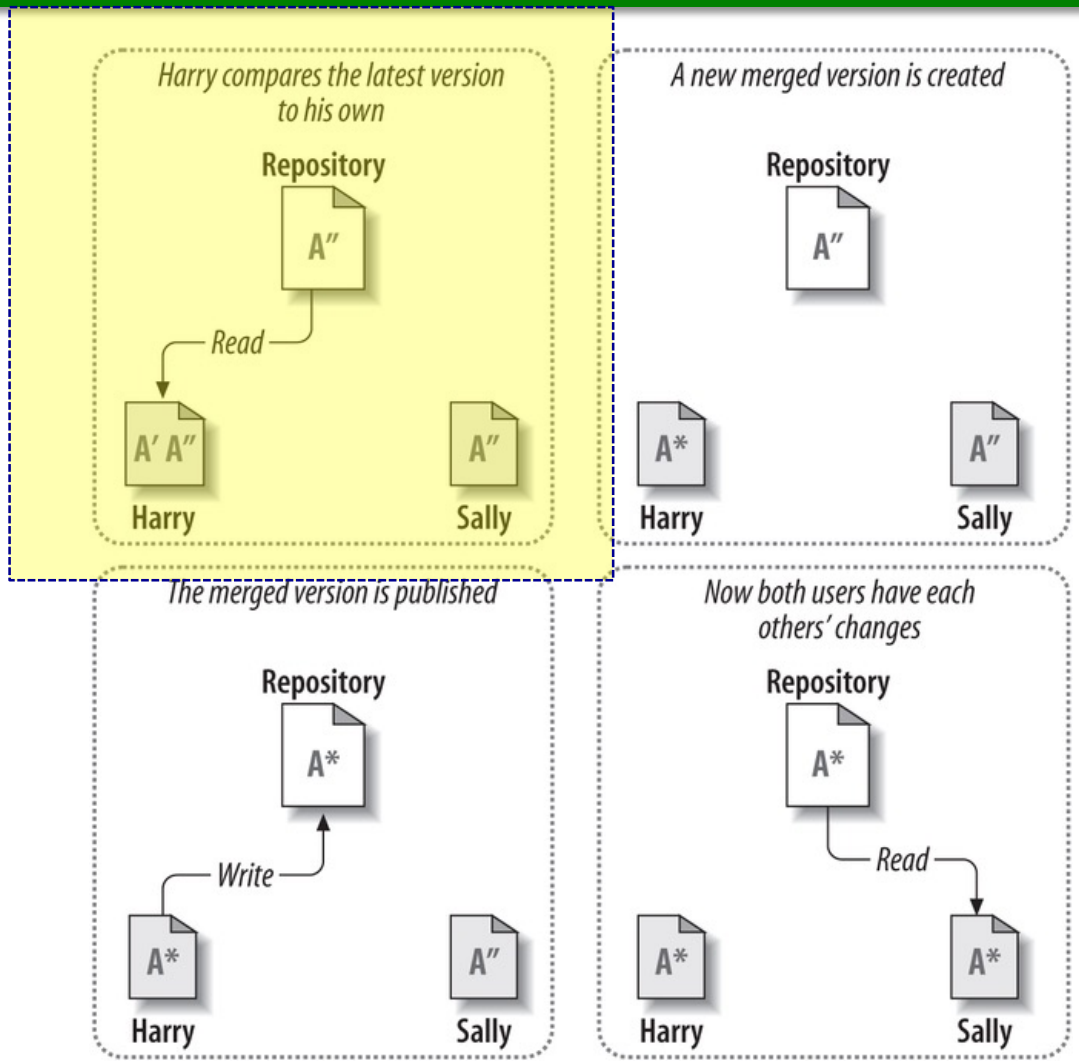
"Copy-modify-merge" solution

scenario: conflict is introduced



"Copy-modify-merge" solution

scenario: conflict is resolved



Observations

- **Copy-modify-merge** allows users to work in parallel
  - Most concurrent changes do not overlap
  - Consistency amongst files is explicitly managed (i.e., no false sense of security)
- This model assumes files are line-based text files
  - Assumes changes can (usually) be "merged" (i.e., combined)

More observations

- For binary files, very difficult (if not impossible) to merge conflicting changes
  - JPEG files
  - Object files and executable images
- However, we may still want to keep such items in the repository
  - Also: there exist "text" versions of some image formats (PNG, SVG)
- git does not support the notion of "release numbering"
  - As there may not be a global shared repo, no global number is possible
  - git instead associates a hash with each commit…
  - … which is actually a SHA-1 checksum of the git object created by the commit)

What is git?

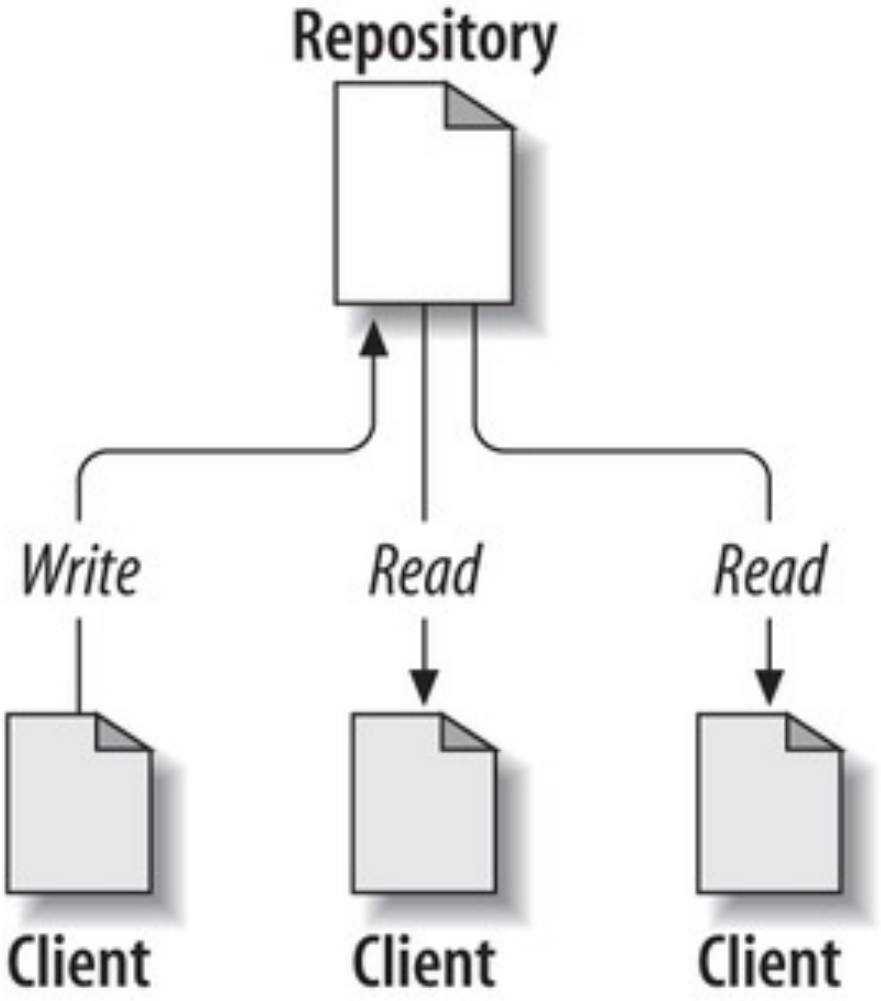
- **A framework for version-control system workflows**
- Tracks changes to files and directories over time
  - These files/directories are usually associated with some software development project – but it need not be software.
- Resembles some features of a file system yet:
  - Remembers changes to all files and directories managed by the repository
  - Sometimes behaves like a time machine for files and directories
- Permits concurrent access to a repository over a network
  - This facilitates work on shared projects, therefore also enhances collaboration
  - Some technologists use services such as GitHub as a one-stop data repository

Some git history

- Proprietary distributed VCS (BitKeeper) had been used by the Linux kernel dev team
- When this was no longer available (2005), Linus Torvalds started work on a replacement
- Idea:
  - git is a "lower-level" VCS
  - front-ends can be created to provide different VCS workflows
- GitHub (2008) made git widely known by combining repository hosting with a simplified git workflow

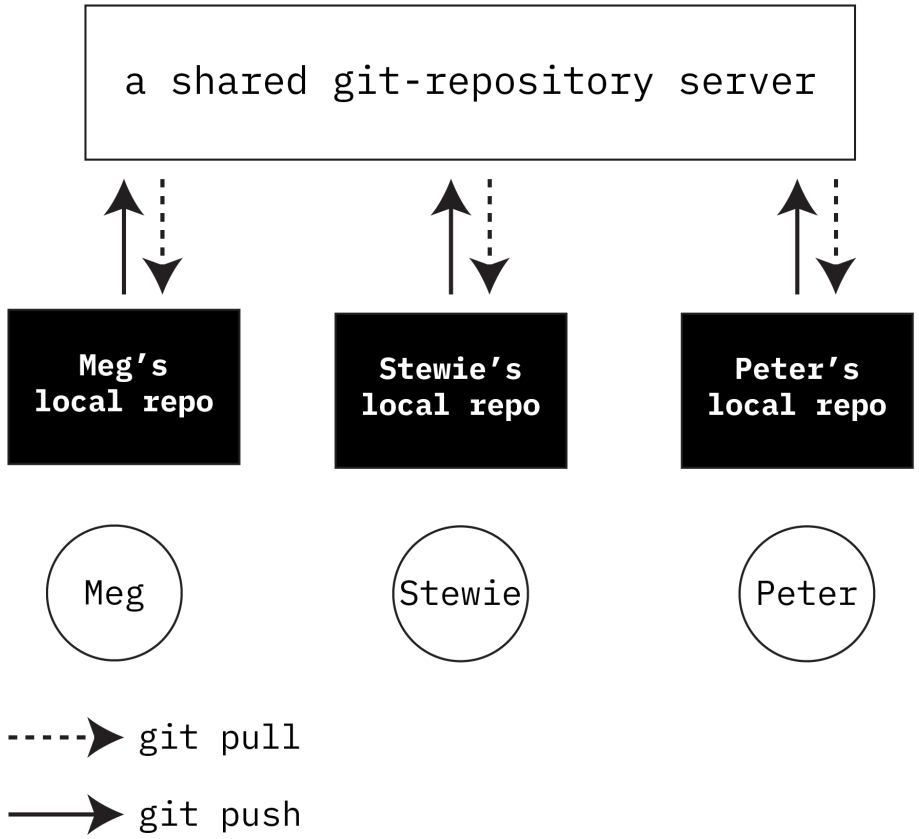
Basic Concepts: Repository

- A VCS **repository** is a store of data and metadata
- Repositories may be stored on remote **repository servers**
- Data could be visualized as stored in something **resembling** a filesystem tree
- Any number of **clients** can connect to the repository
  - These clients can then read and write files in the repository
- By writing (e.g., committing) files, client makes files available to other clients
- By reading (e.g., updating) files, client is receiving information from other clients



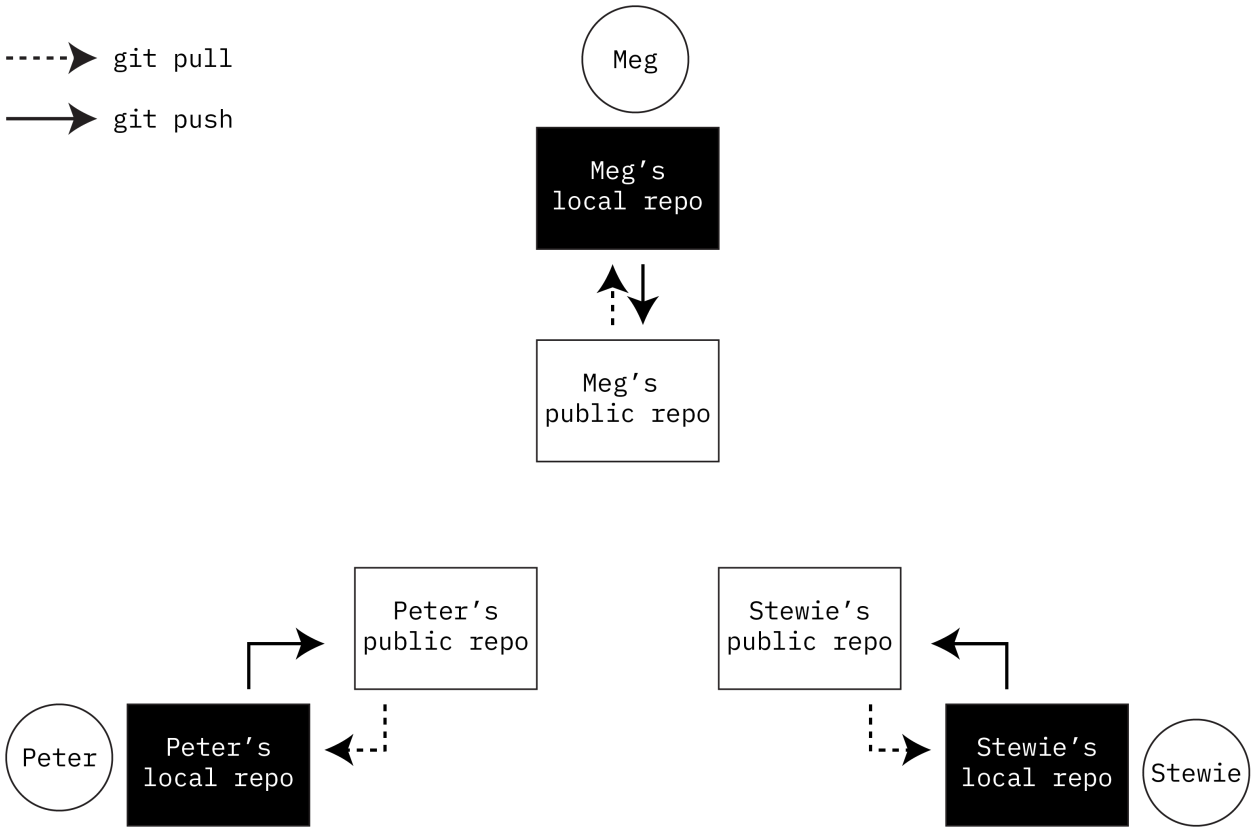
The git twist

- Git combines together the local repo with a working copy
- Git is often used assuming a shared repository….
- In "git-lish":
  - Writing to remote repo == **push**
  - Reading from remote repo == **pull**



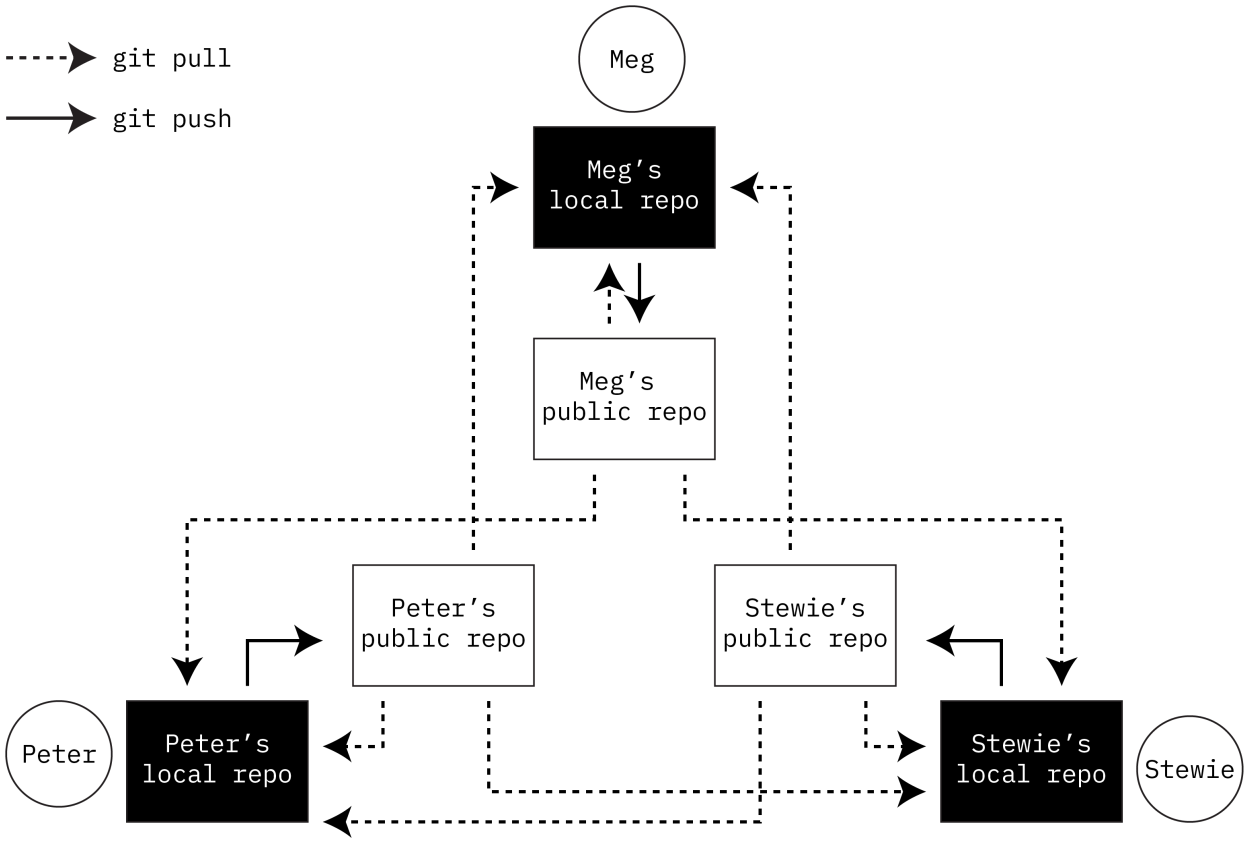
The git twist

- … and git can be used in a more distributed manner
- This means:
  - Developers have read/write (i.e., full push/pull) access on their repo
  - They can have read (i.e., pull) access on repos from other team members
- One level of links shown here…



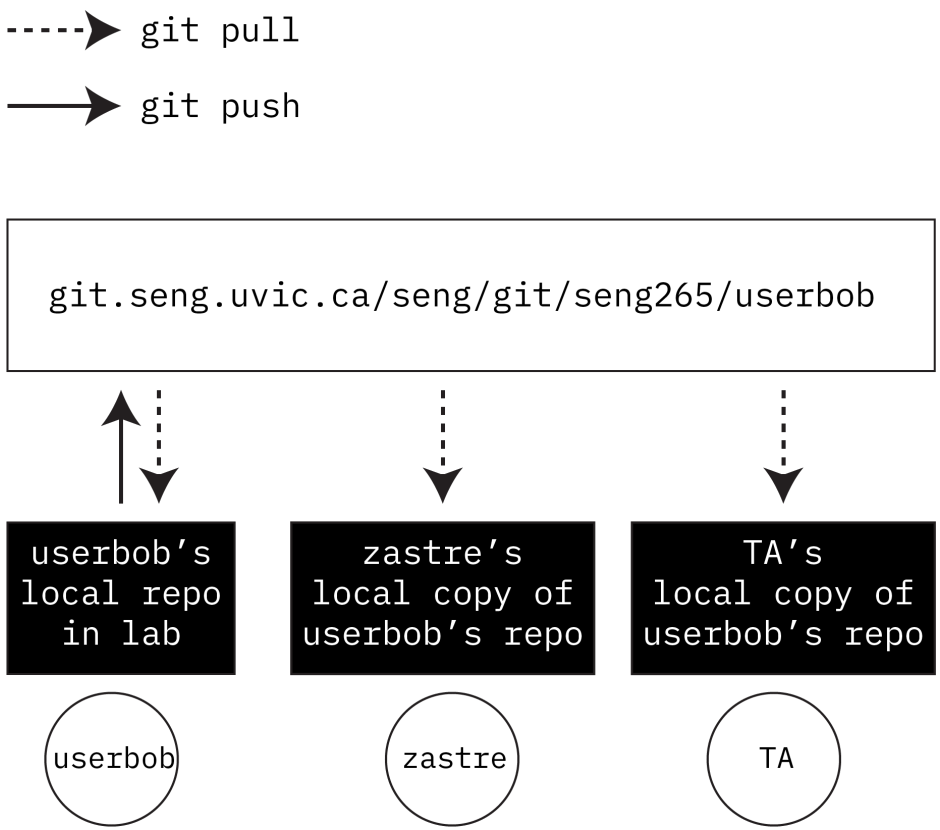
The git twist

- … and an additional level of links is shown here
- With distributed repos, there is no longer necessarily a single repo with all of the code
  - In practice, one team member becomes the "repository of record" (maybe it should be Stewie?



git for UVic's seng265

- Each student has their own repository on git.seng.uvic.ca/seng265
- Each student can both push and pull (read and write) on their **remote**
- Students cannot push or pull other student repos
- Teaching team able to pull from (but not push to!) student repos
- Note that students could have multiple local copies of the same repo. Achtung!



Basic general git cycle (assuming shared repo)

1. Either:
   - perform a **`clone`** to make a working copy of some remote repo's branch, or
   - perform a **`init`** plus other actions to connect this new local repo with a (possibly empty) remote repo branch
2. In your working copy of the project (which is a directory):
   - edit files or
   - create files the project or
   - do both
3. If needed, update our local copy with a **`pull`** (and perhaps also a **`merge`**)
   - this picks up changes made by team members / project participants since your last update
4. build / run / test / view / render / read / <fill-in-verb> your work
5. **`add`** the name of changed files that are ready to be committed in your local repo ("staging")
6. **`commit`** your changes to your local repo
7. if changes are not yet ready to be sent on the remote repo, go to 2
8. **`push`** committed changes to the remote repo
9. go to step 2

Basic Concepts: Working Copy

- Obtaining a working copy means either **cloning** an existing repository or performing **init** in some existing directory
  - This is normally done **only once** per working copy
  - All work is done in a (you guessed it!) working copy
  - Working copy is simply a set of directories & files
- Repository access methods differ:
  - direct access via local disk (file:///) **(ugh!)**
  - via ssh:// (**we'll use ssh in the labs and for assignments**)
  - http or https (as used by GitHub and GitLab)
  - original access method for working copy / local repo is stored as metadata in .git subdirectories in that working copy)

Please do not use **git init** for this course!

Basic Concept: Working Copy

- Example: get working copy of the "calc" project from git.example.com

```
$ git clone ssh://stewie@git.example.com/repos/calc
Cloning into 'calc'...
<password for stewie>
remote: Counting objects: 37, done.
remote: Compressing objects: 100% (31/31), done.
remote: Total 37 (delta 5), reused 0 (delta 0)
Receiving objects: 100% (37/37), done.
Resolving deltas: 100% (5/5), done.
Checking connectivity... done.

$ cd calc
$ git ls-files  # could even use `tree` here...
Makefile
button.c
integer.c

$
```

Basic Concepts: Commit

- Suppose you wish to keep track of some changes to **button.c**
  - You edit the file using your normal workflow
  - Time and date on edited file will be more recent than time and date of file in local repo
  - Changes are recorded by committing your changed file to the repository
- We first stage our changes (via **add**)…
- … and then make a "permanent" record of the change (**commit**)

```
$ pwd
calc

$ git add button.c
$ git commit -m "Fixed the geometry of button for v3 of library"
[master 12788ce] Fixed the geometry of button for v3 of library
 1 file changed, 1 deletion(-)
$
```

Basic Concepts: Commit

- Note that commits are **always** to our local repo
  - i.e., take place within our working/local copy
- We can have a sequence of **many** such commits as we work through sets of changes
- **To have the results of the commits available to others...**
  - **... or to ourselves on a different machine ...**
  - **... we must push them to a remote repository**
- Observations:
  - Commits can be quite frequent (if needed by our workflow)
  - **Pushes are much less frequent** (with such a push perhaps reflecting our work has reached some suitable state and is ready for other team members to pull).
  - Example: writing and completing each assignment will require several commits
  - Example: submitting an assignment will require at least one push

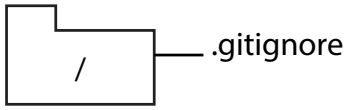
Basic Concepts: Commit

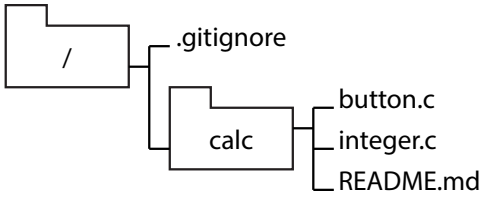
- Each **commit** results **in the creation of a new snapshot of the contents** in our working copy / local repository
- Snapshots are kept in chronological order
  - **git log** produces a list of the snapshots
  - Default log output order is reverse chronological (i.e., most recent commit/snapshot is listed first)
- **git status** reports the relationship amongst files in our working directory with what within git's local repository
  - More precisely, "status" tells us what has changed in our working directory…
  - … and therefore what may need to be "add"ed and "commit"ed to the local repository

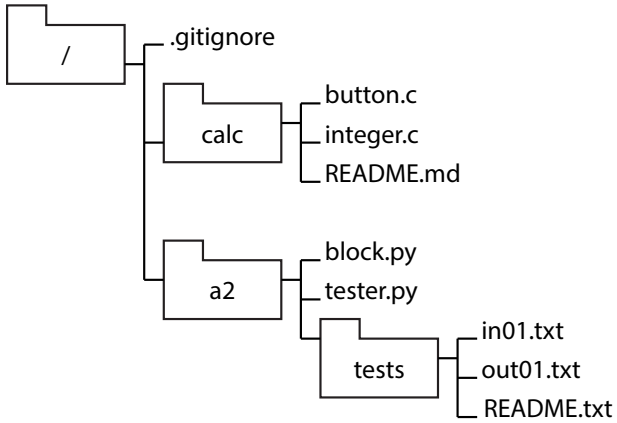
Basic Concepts: Commit

time

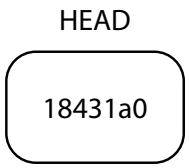
files

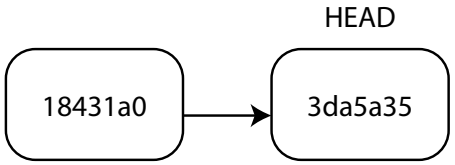


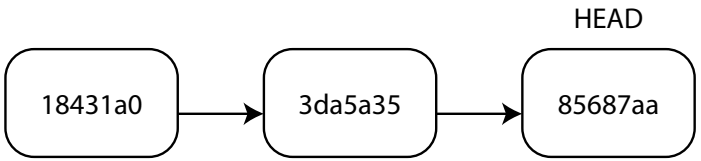




snapshots







note

initial commit

commit after adding "calc" with its files

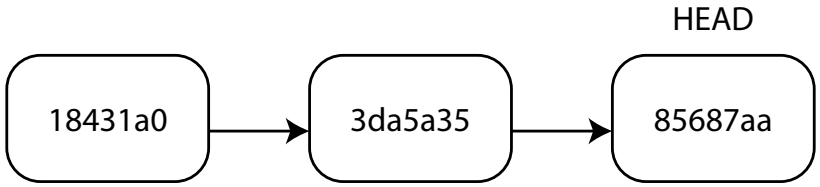
commit after adding "a2" with its files and subdirectory

(steps leading to third commit)

```
$ pwd
/home/stewie/project

$ git add *  # Let git know what files are to be committed; recursive on directories

$ git status
On branch master
Your branch is ahead of 'origin/master' by 1 commit.
  (use "git push" to publish your local commits)

Changes to be committed:
  (use "git reset HEAD <file>..." to unstage)

    new file:   a2/block.py
    new file:   a2/tester.py
    new file:   a2/tests/README.txt
    new file:   a2/tests/in01.txt
    new file:   a2/tests/out01.txt

$ git commit -m "Now the A#2 directory (a2) is in place"  # Note message
[master 85687aa] Now the A#2 directory (a2) is in place
 5 files changed, 6 insertions(+)
 create mode 100644 a2/block.py
 create mode 100644 a2/tester.py
 create mode 100644 a2/tests/README.txt
 create mode 100644 a2/tests/in01.txt
 create mode 100644 a2/tests/out01.txt
```

Basic Concepts: Commit

```
$ git log
commit 85687aa056e299897153a3125c1826f64581bdc5
Author: Stewie Griffin <stewie@uvic.ca>
Date:   Thu Apr 15 10:05:54 2018 -0700

    Now the A#2 directory (a2) is in place

commit 3da5a353956c320fbe8e585cd692b173e44b06c1
Author: Stewie Griffin <stewie@uvic.ca>
Date:   Thu Apr 15 10:01:57 2018 -0700

    Added calc and some files

commit 18431a0b85f0645c98e4cceb311074594a19a38d
Author: Stewie Griffin <stewie@uvic.ca>
Date:   Thu Apr 15 09:38:34 2018 -0700

    Initial commit (just .gitignore for now)
$
```



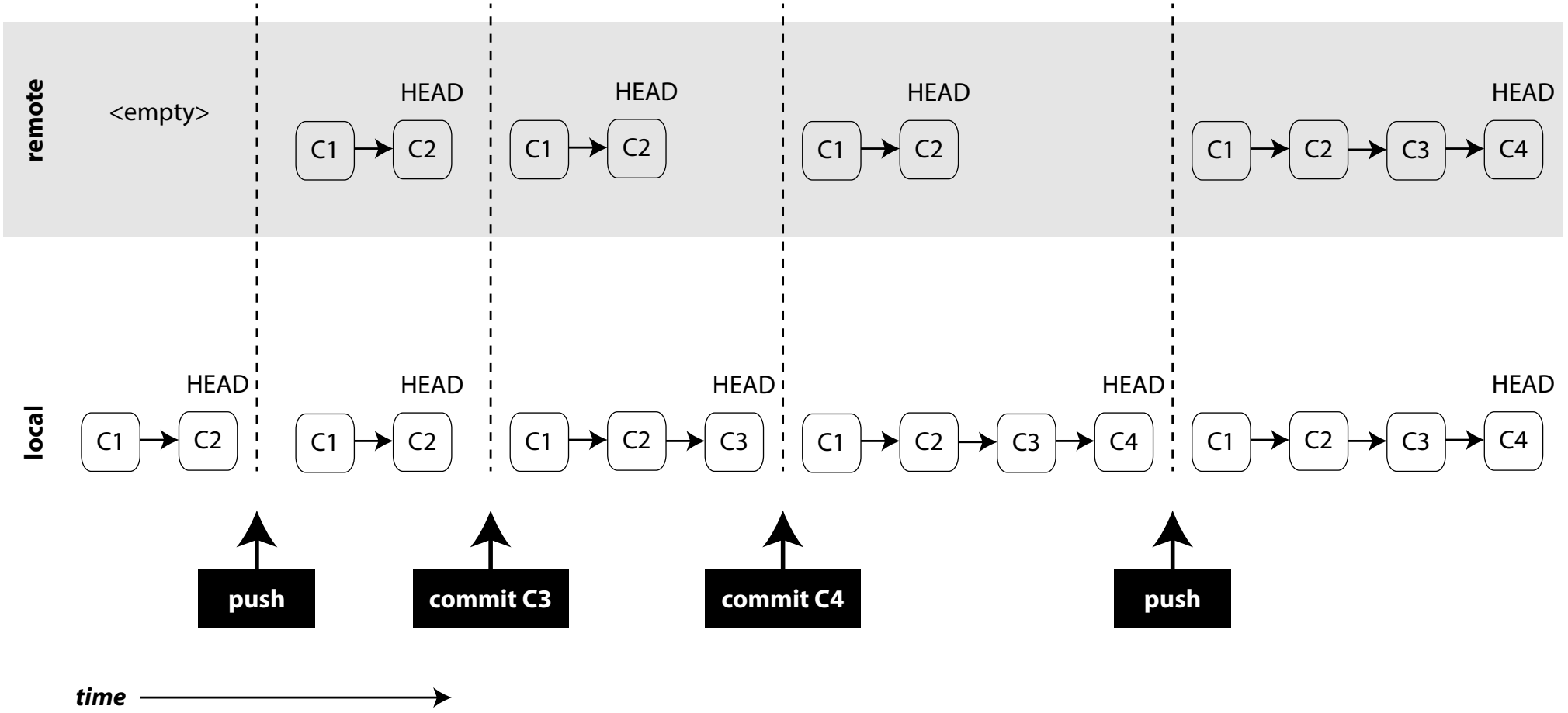
Basic Concepts: Commit

```
$ git status
On branch master
Your branch is ahead of 'origin/master' by 2 commits.
  (use "git push" to publish your local commits)

nothing to commit, working directory clean

$ git push
<verbiage>
<password for stewie>
Counting objects: 13, done.
Delta compression using up to 8 threads.
Compressing objects: 100% (10/10), done.
Writing objects: 100% (12/12), 1.11 KiB | 0 bytes/s, done.
Total 12 (delta 0), reused 0 (delta 0)
To ssh://stewie@git.example.com/project
   18431a0..85687aa  master -> master

$ git status
On branch master
Your branch is up-to-date with 'origin/master'.

nothing to commit, working directory clean

$
```

commit != push

- git is different from many other kinds of VCSes
  - commits are made to the local repo, **not the remote**
  - making these changes available to others means transferring data from the local repo to the remote repo (i.e., a push)
- git separates **the tracking of file/directory changes** from **their storage on remote servers/repositories**
  - this is very different from Subversion, Perforce, etc.
  - ... and can seem a bit confusing on first encounter

commit != push


remote
local
<empty>
HEAD
C1
C2
C3
C4
push
commit C3
commit C4
push
time

Basic Concepts: Update

- What if Meg starts working on the project after someone else's commit?
  - Assume she made a working copy of Stewie's repo some time ago
  - (Also assume here she has read & write privileges on Stewie's remote.)
  - Let's also assume she was not working on button.c in calc
- She can ask git to bring her working copy "up to date"
  - git will only update files for which there are changes on the remote
  - Principle: Make sure to update often if working with a group on a project that uses a repository!

```
$ pwd
/home/meg/calc

$ git pull
<password for meg>
remote: Counting objects: 7, done.
remote: Compressing objects: 100% (4/4), done.
<... snip ...>
Fast-forward
 calc/button.c | 1 +
 1 file changed, 1 insertion(+)

$
```

Basic Concepts: Update

- "git pull" is actually two commands together:
  - "git fetch" followed by "git merge"

```
$ pwd
/home/meg/calc

$ git fetch
<password for meg>
remote: Counting objects: 7, done.
<snip>

$ git log --name-status
commit eb6c8a6ffb2e2a70a89e4a89db8d62b5a22eccd4
Author: Stewie Griffin <stewie@uvic.ca>
Date:   Thu Apr 15 10:27:23 2018 -0700
    Added headers so buttons can be beveled

M       calc/button.c
```

Basic Concepts: Update

```
$ pwd
/home/meg/calc

$ git merge origin/master
Updating 85687aa..eb6c8a6
Fast-forward
 calc/button.c | 3 +++
 1 file changed, 3 insertions(+)
$
```

- Therefore "git pull" is the same as the following two commands in succession
  - git fetch
  - git merge origin/master
- We used "git log --name-status" to obtain the names of files that are different from our working copy and the remote repo

What is with "origin"? "master"?

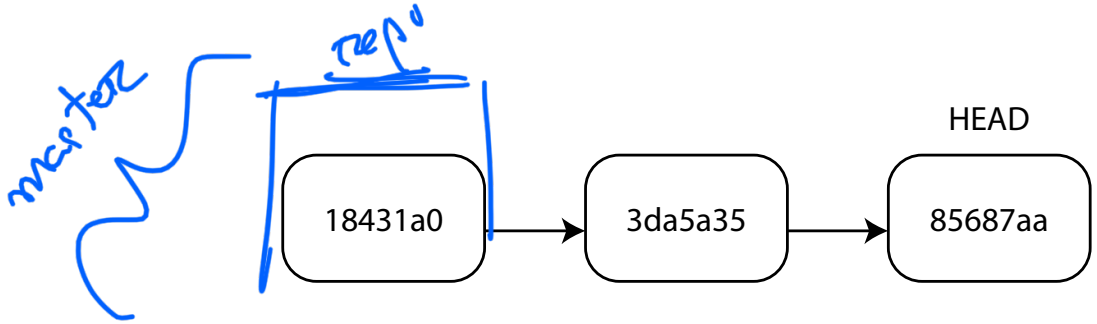
- A working copy / local repo may be associated with:
  - No remote repo, or
  - **One remote repo** (UVic SENG 265) or
  - Several remote repos.
- A working copy / local repo may have:
  - No code branches tracked by git, or
  - **One code branch** (UVic SENG 265) tracked by git, or
  - Several code branches tracked by git.
- By git convention, the default **remote repo** is named **origin**.
- By convention, the **main branch** of code development is named **master** (i.e., it is the "master" or "main branch" of code development)

What is with "origin"? "master"?

```
$ pwd
/home/stewie/calc

$ git remote -v
origin  ssh://stewie@git.example.com/repo/calc (fetch)
origin  ssh://stewie@git.example.com/repo/calc (push)

$ git branch -v
* master b5b22e2 Bevels now in place
```

- When using "git pull" and "git push" for repos already cloned:
  - origin & master are **usually** default values
  - "git pull" == "git pull origin master"
  - "git push" == "git push origin master"
- Note: We'll discuss branching workflows later in the term

What is with "origin"? "master"?



- This diagram we saw earlier of our commits / snapshot is an example of a **branch**
- The git convention is that every repo has **at least one branch** which is the main branch
  - Usually referred to as the **master** branch.
- Above is shown master branch from slide 24 (i.e., project with "calc", "a2" directories and their subdirectories/files).

A "gotcha" with git add

- This is a bit more subtle in git
- **add** results in a file or directory being staged for commit
- When **commit** is performed, changes to staged files are stored into the local repo
- Note, however:
  - Every file or directory in the project that is to be tracked by git needs to be added **at least once in the project's lifetime**
  - Also: **add** gives us fine-grained control as to what needs to be in a specific commit's snapshot
  - Sometimes, though, we just want all of the changed files to be staged and committed without having to use **add**
  - **`git commit -a -m "message"`**

Never store generated files in the repository.

For example, if your project includes C source code, you would store the .c and .h files. You would not store the .o or executables.

If your project includes Java source code, you would store the .java file, but you wouldn't store the generated .class or .jar files.

Use .gitignore

- This text file needs to be committed to the project
- Normally stored in the top-level of the working directory
- Each line in the file is used as a pattern
- Possible entries:

```
*.pyc
*.o
DS_STORE
*.class
```

What about "conflicts"?

- Suppose you've fetched changes and merged them into your master branch
- Normally we see a clean report of git's work
  - Downloading objects from remote
  - Merging changes into our working copy (i.e., new files, removed files, edits to existing files)

```
$ git pull
<password>
remote: Counting objects: 19, done.
remote: Compressing objects: 100% (14/14), done.
remote: Total 18 (delta 1), reused 0 (delta 0)
Unpacking objects: 100% (18/18), done.
From ssh://git.example.com/repo/calc
   b5b22e2..4955e13  master     -> origin/master
Updating b5b22e2..4955e13
Fast-forward
 calc/README.md      | 4 ++++
 calc/main_init.py   | 3 +++
 calc/guiframe.py    | 1 +
 3 files changed, 8 insertions(+)
 create mode 100644 calc/README.md
 create mode 100644 calc/main_init.py
 create mode 100644 calc/guiframe.py
```

What about "conflicts"?

- However, sometimes we don't see a clean report

What about "conflicts"?

- However, sometimes we don't see a clean report
- Scenario:
  - Meg has pulled from the remote. Both she and Stevie have the first version of button.c shown here.

```
/* button.c */

#include <stdio.h>
#include <gui.h>
```

What about "conflicts"?

- However, sometimes we don't see a clean report
- Scenario:
  - Meg has pulled from the remote. Both she and Stevie have the first version of button.c shown here.
  - Stevie makes a change to calc/button.c, **but doesn't commit**

```
/* button.c */

#include <stdio.h>
#include <gui.h>
```

```
/* button.c */

#include <stdio.h>
#include <gui.h>

/* I, Stevie, am the smartest Griffin */
int _init_button (int id, int skin,
    char *label) { /* A stub, I say! */ }
```

What about "conflicts"?

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- Scenario:
  - Meg has pulled from the remote. Both she and Stevie have the first version of button.c shown here.
  - Stevie makes a change to calc/button.c, **but doesn't commit**
  - Meg makes a change to calc/button.c, **then commits and pushes it**.

```
/* button.c */

#include <stdio.h>
#include <gui.h>
```

```
/* button.c */

#include <stdio.h>
#include <gui.h>

/* I, Stevie, am the smartest Griffin */
int _init_button (int id, int skin,
    char *label) { /* A stub, I say! */ }
```

```
/* button.c */

#include <stdio.h>
#include <gui.h>

void _init_button (int code, int look,
    char *title) { /* For you, Connie! */ }
```

What about "conflicts"?

- However, sometimes we don't see a clean report
- Scenario:
  - Meg has pulled from the remote. Both she and Stewie have the first version of button.c shown here.
  - Stewie makes a change to calc/button.c, **but doesn't commit**
  - Meg makes a change to calc/button.c, **then commits and pushes it**.
  - Afterwards Stewie tries to commit and then push

```
/* button.c */

#include <stdio.h>
#include <gui.h>
```

```
/* button.c */

#include <stdio.h>
#include <gui.h>

/* I, Stevie, am the smartest Griffin */
int _init_button (int id, int skin,
    char *label) { /* A stub, I say! */ }
```

```
/* button.c */

#include <stdio.h>
#include <gui.h>

void _init_button (int code, int look,
    char *title) { /* For you, Connie! */ }
```

What about "conflicts"?

```
meg$ git add button.c
meg$ git commit -m 'That will be a swell looking button!'
[master bda4b22] That will be a swell looking button!
 1 file changed, 4 insertions(+)
meg$ git push
<password>
<... snip ...>
Total 4 (delta 1), reused 0 (delta 0)
To ssh://stewie@git.example.com/repo/calc
   15c486a..bda4b22  master -> master
```

```
stewie$ $ git commit -a -m "A sterling job, I say, with _init_button."
[master 6708583] A sterling job, I say, with _init_button.
 1 file changed, 4 insertions(+)
stewie$ git push
<password>
<... snip ...>
error: failed to push some refs to 'ssh://stewie@git.example.com/repo/calc'
hint: Updates were rejected because the remote contains work that you do
hint: not have locally. This is usually caused by another repository pushing
hint: to the same ref. You may want to first integrate the remote changes
hint: (e.g., 'git pull ...') before pushing again.
hint: See the 'Note about fast-forwards' in 'git push --help' for details.
stewie$ curses!
-bash: curses!: command not found
```

What about "conflicts"?

```
stewie$ $ git pull
<password>
remote: Counting objects: 7, done.
remote: Compressing objects: 100% (4/4), done.
remote: Total 4 (delta 1), reused 0 (delta 0)
Unpacking objects: 100% (4/4), done.
From ssh://git.example.com/repo/calc
   15c486a..bda4b22  master     -> origin/master
Auto-merging calc/button.c
CONFLICT (content): Merge conflict in calc/button.c
Automatic merge failed; fix conflicts and then commit the result.

stewie$ git status
-On branch master
Your branch and 'origin/master' have diverged,
and have 1 and 1 different commit each, respectively.
  (use "git pull" to merge the remote branch into yours)

You have unmerged paths.
  (fix conflicts and run "git commit")

Unmerged paths:
  (use "git add <file>..." to mark resolution)

        both modified:   button.c

no changes added to commit (use "git add" and/or "git commit -a")
```

Resolving a merge conflict (what Stewie sees)

```
/* button.c */

#include <stdio.h>
#include <gui.h>

<<<<<<< HEAD
/* I, Stevie, am the smartest Griffin */
int _init_button (int id, int skin,
    char *label) { /* A stub, I say! */ }
=======
void _init_button (int code, int look,
     char *title) { /* For you, Connie! */ }

>>>>>>> bda4b226dc91226a0ab310ad4a7feef2c069b4b4
```

- git indicates the conflict with a bit of markup
  - "<<<<<<< HEAD" to "=======": Stevie's original code
  - "=======" to ">>>>>>> bda4b22…": What Meg pushed

Resolving a merge conflict

- Before Stewie can successfully commit and push his work to the remote, he must resolve the conflict
- There are two parts to this:
  - The **human part** (harder)
  - The **technical part** (easy)
- The human part is to decide what code in button.c should be kept
- The technical part is editing the file in a way reflecting that decision, then commiting (and possibly pushing)

Resolving a merge conflict

```
/* button.c */

#include <stdio.h>
#include <gui.h>

<<<<<<< HEAD
/* I, Stevie, am the smartest Griffin */
int _init_button (int id, int skin,
    char *label) { /* A stub, I say! */ }
=======
void _init_button (int code, int look,
     char *title) { /* For you, Connie! */ }

>>>>>>> bda4b226dc91226a0ab310ad4a7feef2c069b4b4
```

before

```
/* button.c */

#include <stdio.h>
#include <gui.h>

int _init_button (int id, int skin,
    char *title) { /* This stub is to be completed */ }
```

after

What about "conflicts"?

```
stewie$ $ vim calc/button.c
<actions to edit the file>

stewie$ git commit -a -m "button.c now back on track"
[master 8d0c566] button.c now back on track

stewie$ git push
<password>
<... snip ...>
Counting objects: 14, done.
Delta compression using up to 8 threads.
Compressing objects: 100% (8/8), done.
Writing objects: 100% (8/8), 1.04 KiB | 0 bytes/s, done.
Total 8 (delta 2), reused 0 (delta 0)
To ssh://stewie@git.example.com/repo/calc
   bda4b22..8d0c566  master -> master
```

```
meg$ git pull
<password>
<... snip ...>
Unpacking objects: 100% (8/8), done.
From ssh://git.example.com/repo/calc
   bda4b22..8d0c566  master     -> origin/master
Updating bda4b22..8d0c566
Fast-forward
 calc/button.c | 5 ++---
 1 file changed, 2 insertions(+), 3 deletions(-)
```

Using git

- **You need a git client**
- In this course we use a command-line client
  - `git` (usually `/usr/bin/git`)
  - provide `git` with commands and arguments
- Note other client possibilities:
  - Git functionality might be built into IDE
  - Git functionality built into tool
  - Some web interfaces for using git (especially needed for GitHub)

Using git

- **For UVic SENG265, you need a repository**
- **Need access to that repository**
- UVic Software Engineering hosts a repository for you:
  - this is on a per-course basis
  - instructions on forming repository address given during lab exercises
- Other possibilities you might encounter:
  - `gibhub`-like services
  - BitKeeper
  - administering your own server (careful!!)

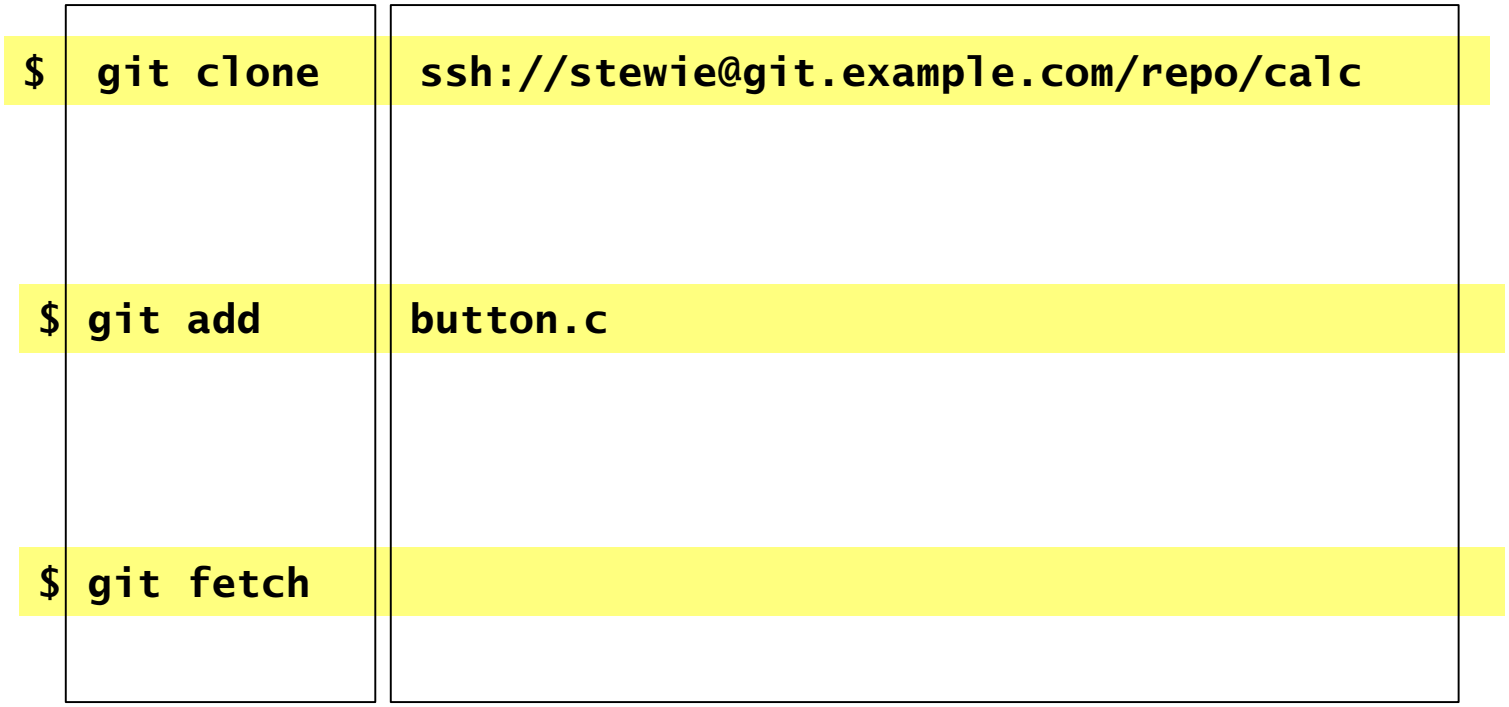
(a wee word…)

- For this course, use the seng265 repository
  - Do not use github!
- Each of your assignments and labs …
  - … will be subdirectories within your repository
  - … which are accessible to the lab instructors and administrators for help when debugging (but accessible to no one else!)
  - … and can be accessed remotely by you

`git` commands

- Note:
  - We've already referred to git "commands"
  - Yet `git` itself **is a UNIX command**
- A `git` command is how we specify an action from the `git` client
- Syntax
  - `git` command [option] [arguments]
- The number of git commands and options is very large
  - We'll be focusing on a much smaller subset of these.
  - (Beware of Google and StackOverflow as answers there can lead you astray…)

Previously seen



A few more examples

```
$ git remote    add origin https://git.420.com/fubar

$ git commit    -a -m "Fixed typo in label"

$ git diff      --name-status HEAD
```

Git command **options & arguments**

Some useful commands

- `clone` make a local copy of a remote repo
- **`add`** stage files/directories so they'll be ready to be committed
- **`commit`** store into local repo a snapshot of working-copy changes
- **`status`** list working copy files/dirs differing from local repo
- **`log`** output commit messages with their snapshot SHA-1 hashes
- `diff` show differences of working-dir contents with local repo
- `pull` fetch and merge into local repo any remote repo changes
- **`push`** transfer local repo snapshots to remote repo
- `fetch` download data for remote changes to local repo (but no more!)
- `merge` combine new remote changes with files in local repo
- **`rm`** remove file from working copy / working tree
- `init` convert working directory into git local repo (caution!)

If you need help…

- For a specific command:
  - `git <command> --help`
  - Provides list of arguments and options
- For info on repository access
  - speak to the provider, or
  - read the provided documentation
  - follow the instructions given in the lab and on the assignments!

A few further topics for (perhaps) later in term

- branch creation, selection and merging
- more complicated merge-conflict resolution
- tags
- multiple remotes
- diffs and blame (and logs in general)
- patches
- setting up repos (init) and setting up git servers