Git, GitHub, and Version Control

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An essential part of modern software engineering is using version control

We use version control because

- Not all iterations on a file are perfect, and you may want to revert changes
- We want to be able to see who has changed what and how
- We want a uniform version scheme to do this between people and machines
- Concurrent editing on code is necessary for collaboration
- Version control is an essential part of creating reproducible research

In this lecture, we'll discuss how to use Git and GitHub

Setup

1. Make sure you create an account on GitHub.com
    - If you are a student, be sure to use the GitHub Student Developer Pack
    - Otherwise, see if you qualify for a free Non-Profit/Academic Plan
    - These come with things like unlimited private repositories, testing support, etc.
2. Install `git` and the GitHub Desktop application
    1. Install git

2. Install the GitHub Desktop application

3. Optionally (but strongly recommended): On Windows, change the default line-ending by:

4. Opening a Windows/Powershell console, or the "Git Bash" installed in the previous step

5. Running the following

```
git config --global core.eol lf
git config --global core.autocrlf false
```

Git vs. GitHub vs. GitHub Desktop

To understand the relationship

- Git is an infrastructure for versioning and merging files (it is not specific to GitHub and does not even require an online server)
- GitHub provides an online service to coordinate working with Git repositories, and adds some additional features for managing projects
- GitHub Desktop is just one of many GUI-based clients to make Git and GitHub easier to use

Later, you may find yourself using alternatives

- GitHub is the market leader for open source projects and Julia, but there are other options, e.g. GitLab and Bitbucket
- Instead of the GitHub Desktop, you may directly use the Git command line, GitKraken, or use the Git functionality built into editors such as Atom or VS Code

Since these lecture notes are intended to provide a minimal path to using the technologies, here we will conflate the workflow of these distinct products

Basic Objects

Repositories

The fundamental object in GitHub is a repository (or "repo") – this is the master directory for a project

One example of a repo is the QuantEcon Expectations.jl package

On the machine, a repo is a normal directory, along with a subdirectory called `.git` which contains the history of changes

Commits

GitHub stores history as a sequence of changes to text, called commits

Here is an example of a commit, which revises the style guide in a QuantEcon repo

In particular, commits have the following features

- An ID (formally, an "SHA-1 hash")
- Content (i.e., a before and after state)
- Metadata (author, timestamp, commit message, etc.)

Note: It's crucial to remember that what's stored in a commit is only the actual changes you make to text

This is a key reason why git can store long and complicated histories without consuming massive amounts of memory

Common Files

In addition, each GitHub repository typically comes with a few standard text files

- A `.gitignore` file, which lists files/extensions/directories that GitHub shouldn't try to track (e.g., LaTeX compilation byproducts)

- A `README.md` file, which is a Markdown file which GitHub puts on the repository website
- A `LICENSE.txt` file, which describes the terms under which the repository's contents are made available

For an example of all three, see the Expectations.jl repo

Of these, the `README.md` is the most important, as GitHub will display it as Markdown when accessing the repository online

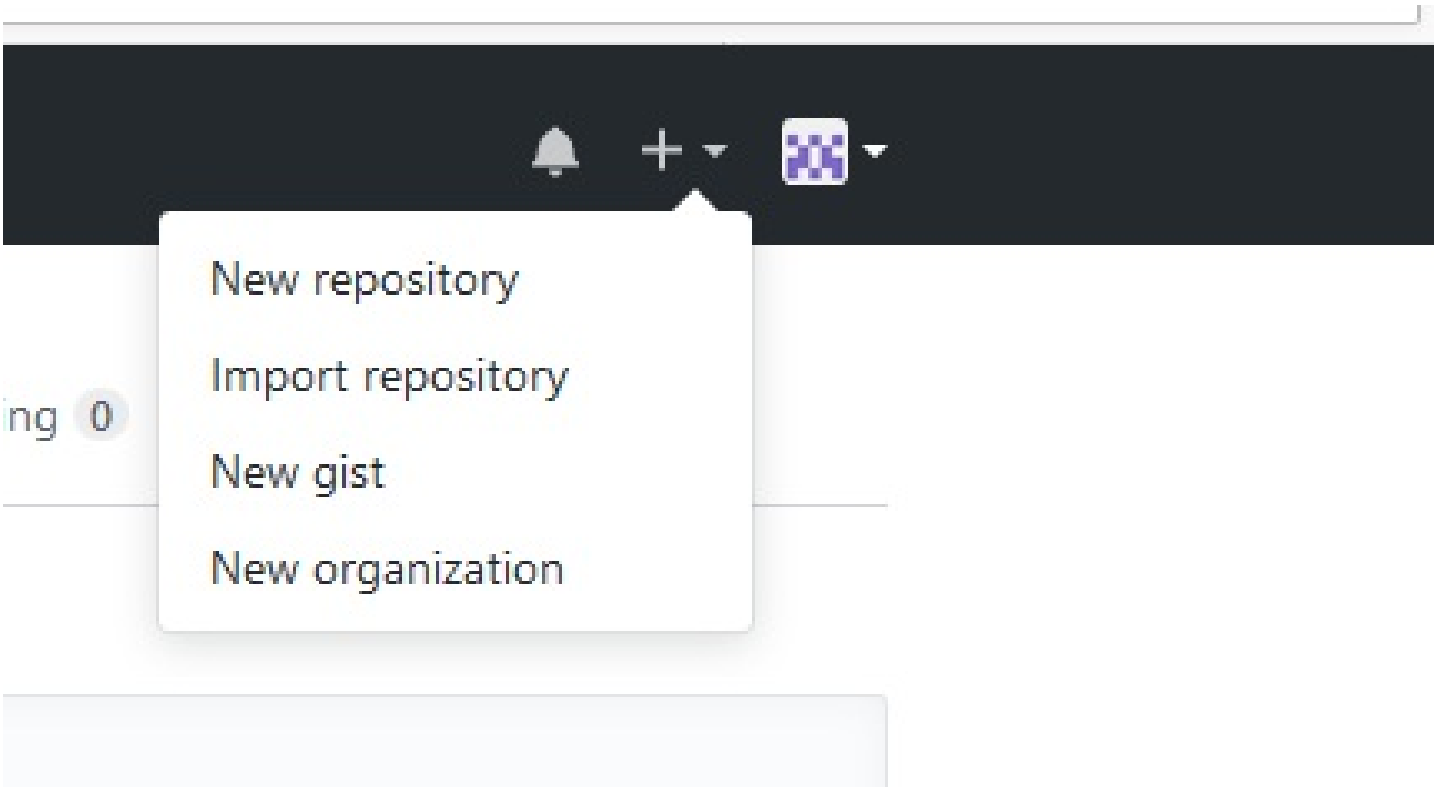
Individual Workflow

In this section, we'll describe how to use GitHub to version your own projects

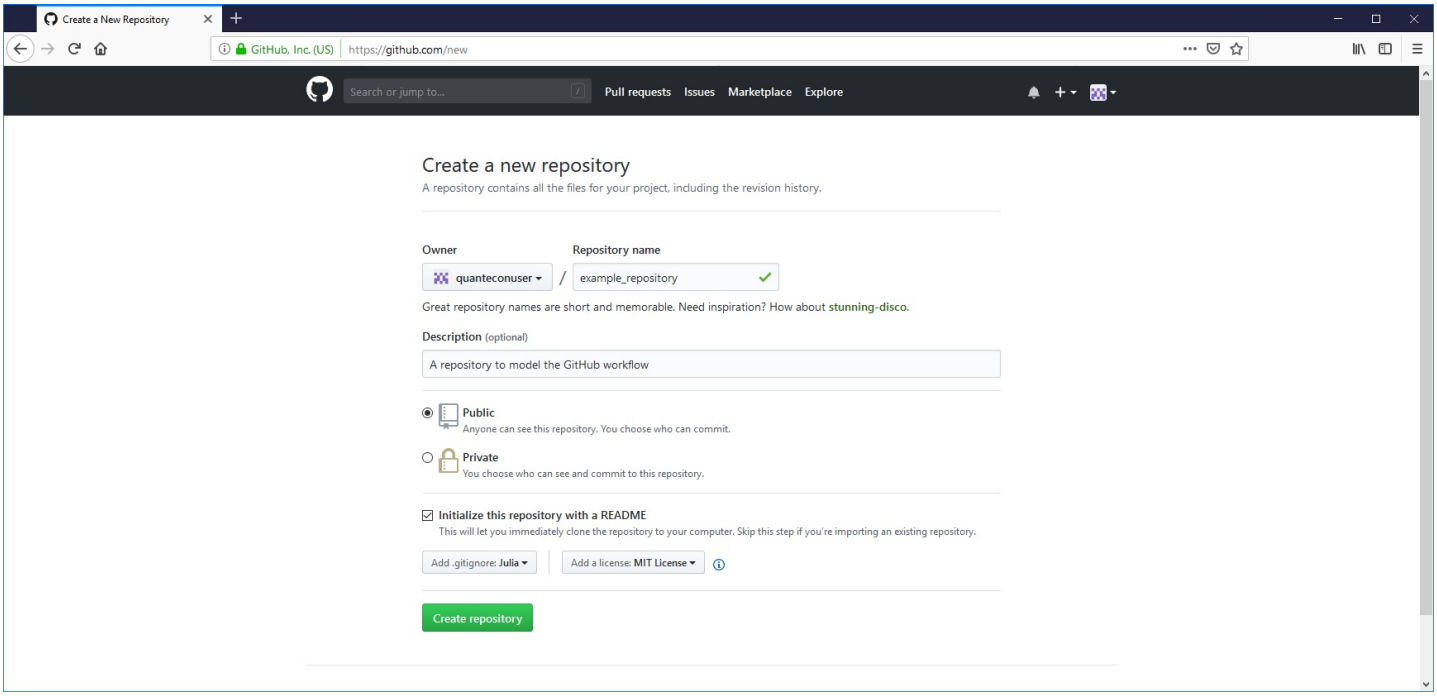
Much of this will carry over to the collaborative section

Creating a Repository

In general, we will always want to repos for new projects using the following dropdown



We can then configure repository options as such



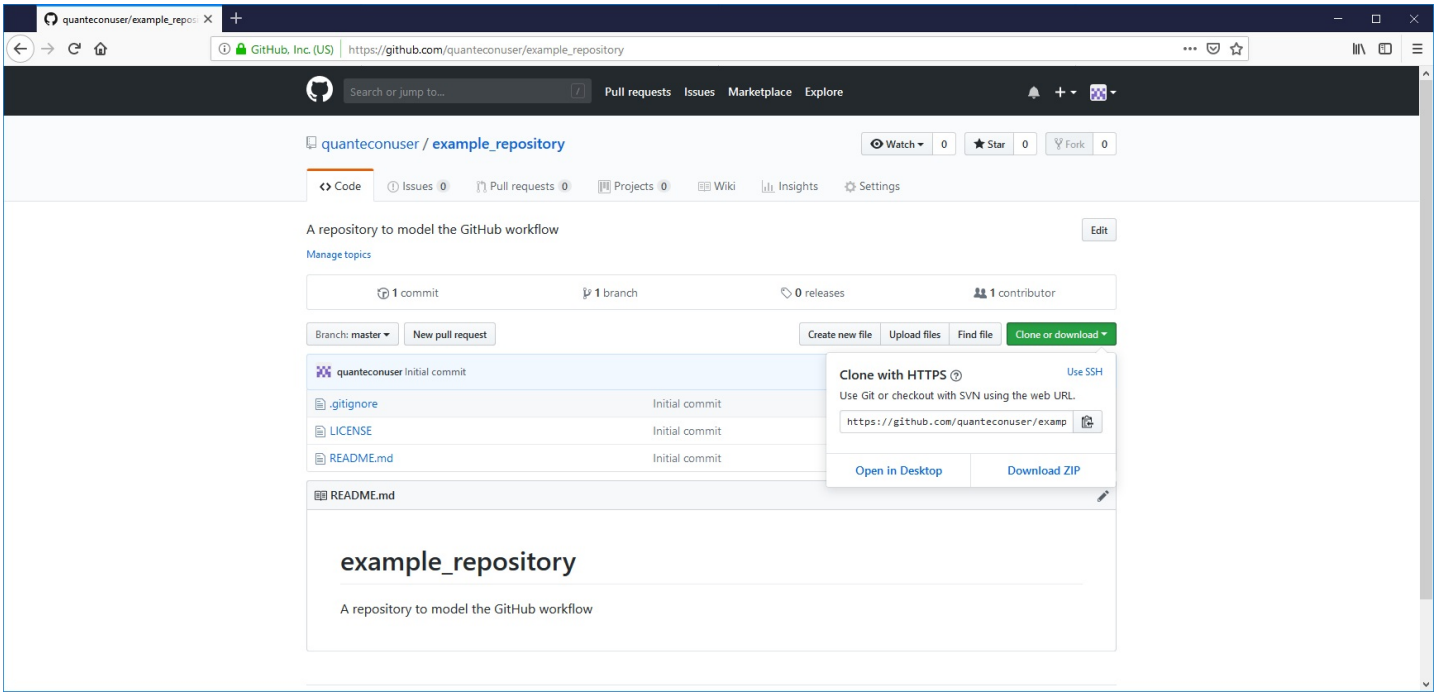
In this case, we're making a public repo `github.com/quantecon_user/example_repository`, which will come with a `README.md`, is licensed under the MIT License, and will ignore Julia compilation byproducts

Note This workflow is for creating projects de novo; the process for turning existing directories into git repos is a bit more complicated

In particular, in that case we recommend that you create a new repo via this method, then copy in and commit your files (see below), and then delete the old directory

Cloning a Repository

The next step is to get this to our local machine



This dropdown gives us a few options

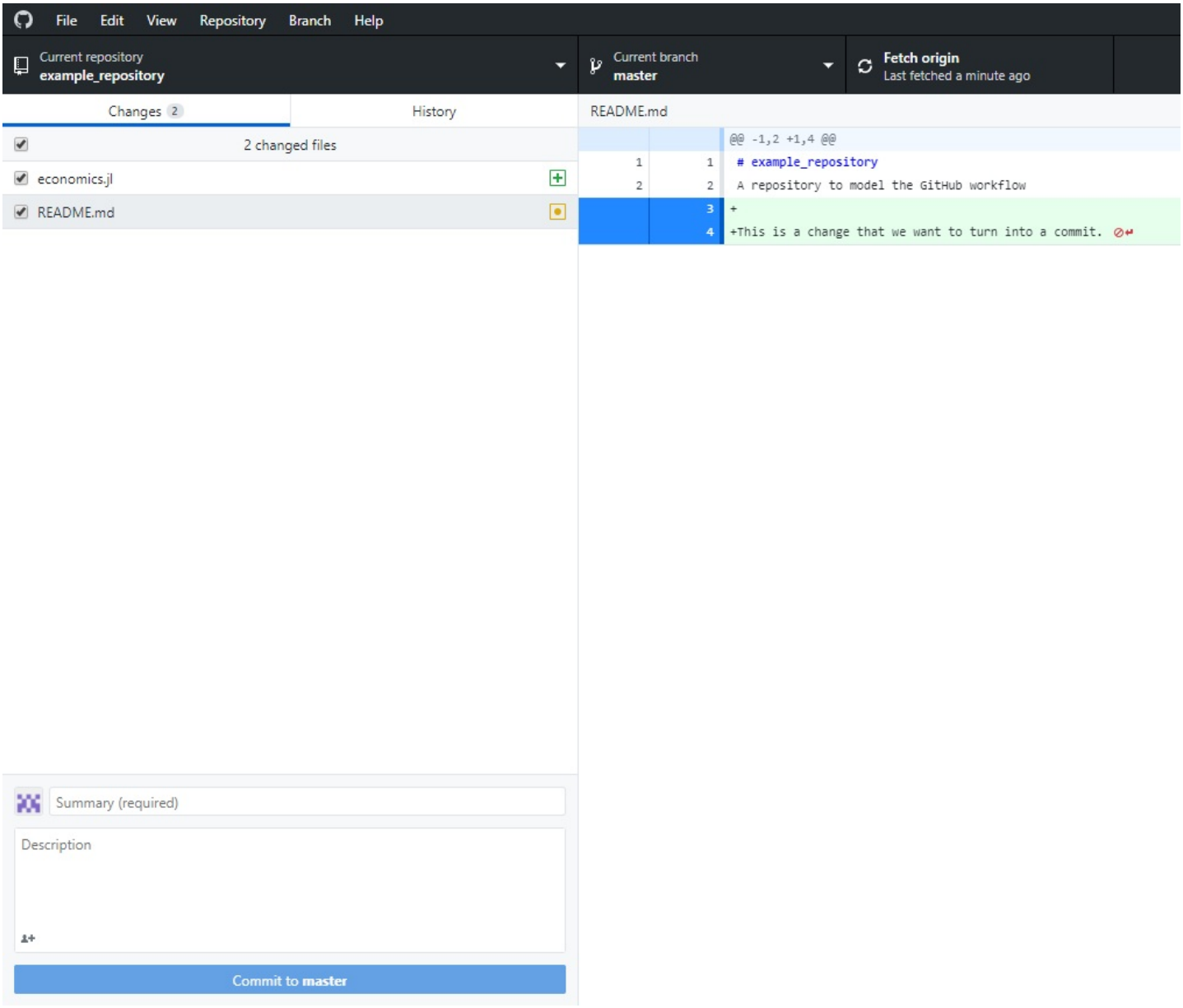
- "Open in Desktop" will call to the GitHub Desktop application that we've installed
- "Download Zip" will download the directory without the .git subdirectory (avoid this option)
- The copy/paste button next to the link lets us use the command line, i.e. `git clone https://github.com/quanteconuser/example_repository.git`

Making and Managing Changes

Now that we have the repository, we can start working with it

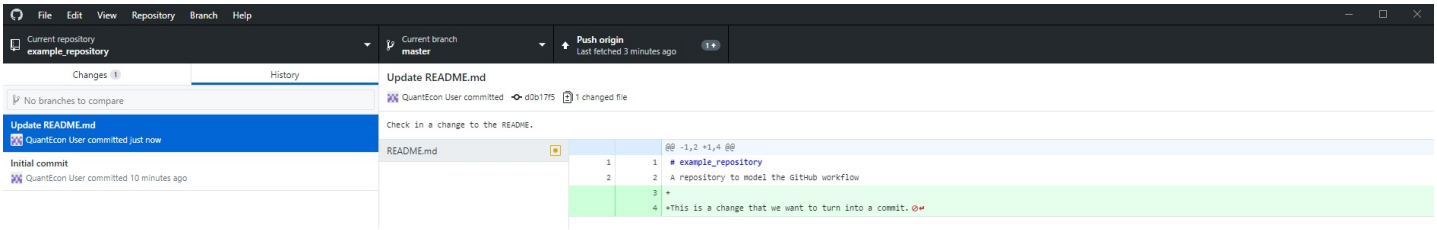
For example, let's say that we've amended the `README.md` (using our editor of choice), and also added a new file `economics.jl` which we're still working on

Returning to GitHub Desktop, we should see something like



To select individual files for commit, we can use the check boxes to the left of each file

Let's say you select only the README to commit. Going to the history tab should show you our change



The Julia file is unchanged

Pushing to the Server

As of now, this commit lives only on our local machine

To upload it to the server, you can simply click the "Push Origin" button at the top the screen

The small "1^" to the right of the text indicates we have one commit to upload

Reading and Reverting History

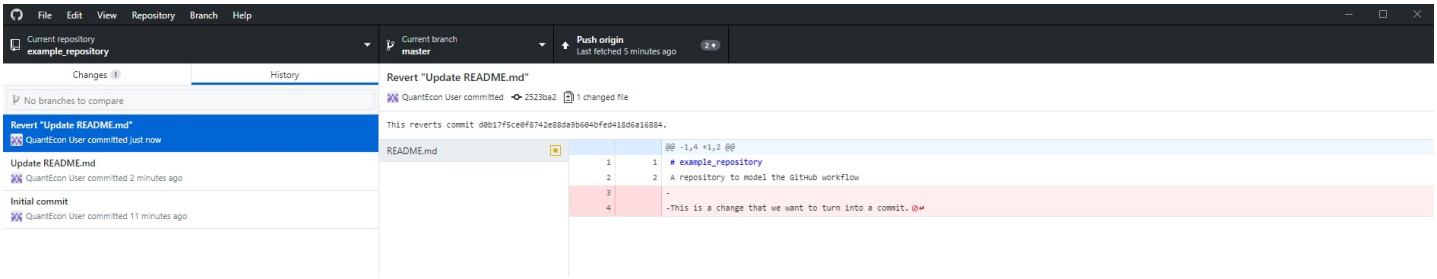
As mentioned, one of the key features of GitHub is the ability to scan through history

By clicking the "commits" tab on the repo front page, we see this page (as an example)

Clicking an individual commit gives us the difference view, (e.g., example commit)

Sometimes, however, we want to not only inspect what happened before, but reverse the commit

- If you haven't made the commit yet, just right-click the file in the "changes" tab and hit "discard changes" to reset the file to the last known commit
- If you have made the commit but haven't pushed to the server yet, go to the "history" tab as above, right click the commit and click "revert this commit." This will create the inverse commit, shown below



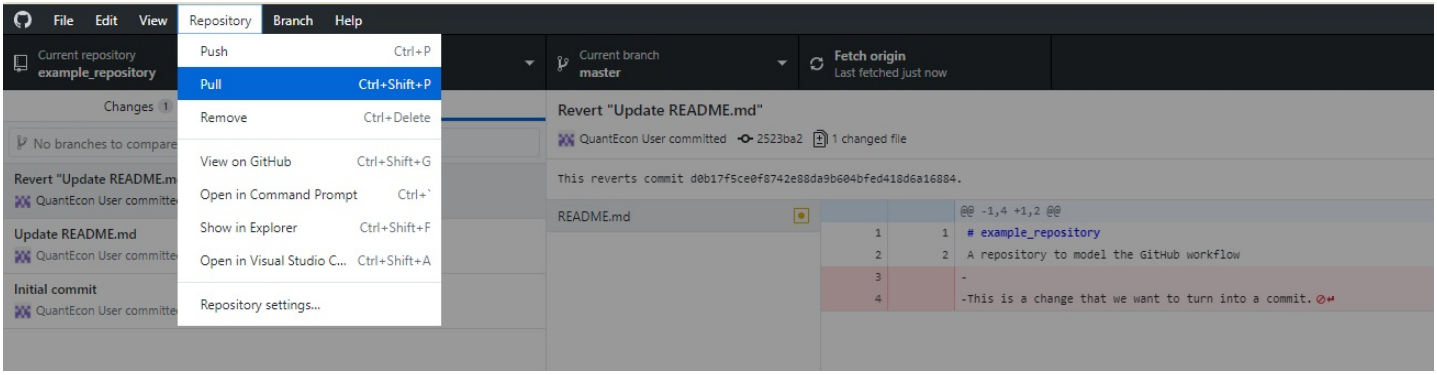
Working across Machines

Generally, you want to work on the same project but across multiple machines (e.g., a home laptop and a lab workstation)

The key is to push changes from one machine, and then to pull changes from the other machine

Pushing can be done as above

To pull, simply click pull under the "repository" dropdown at the top of the screen

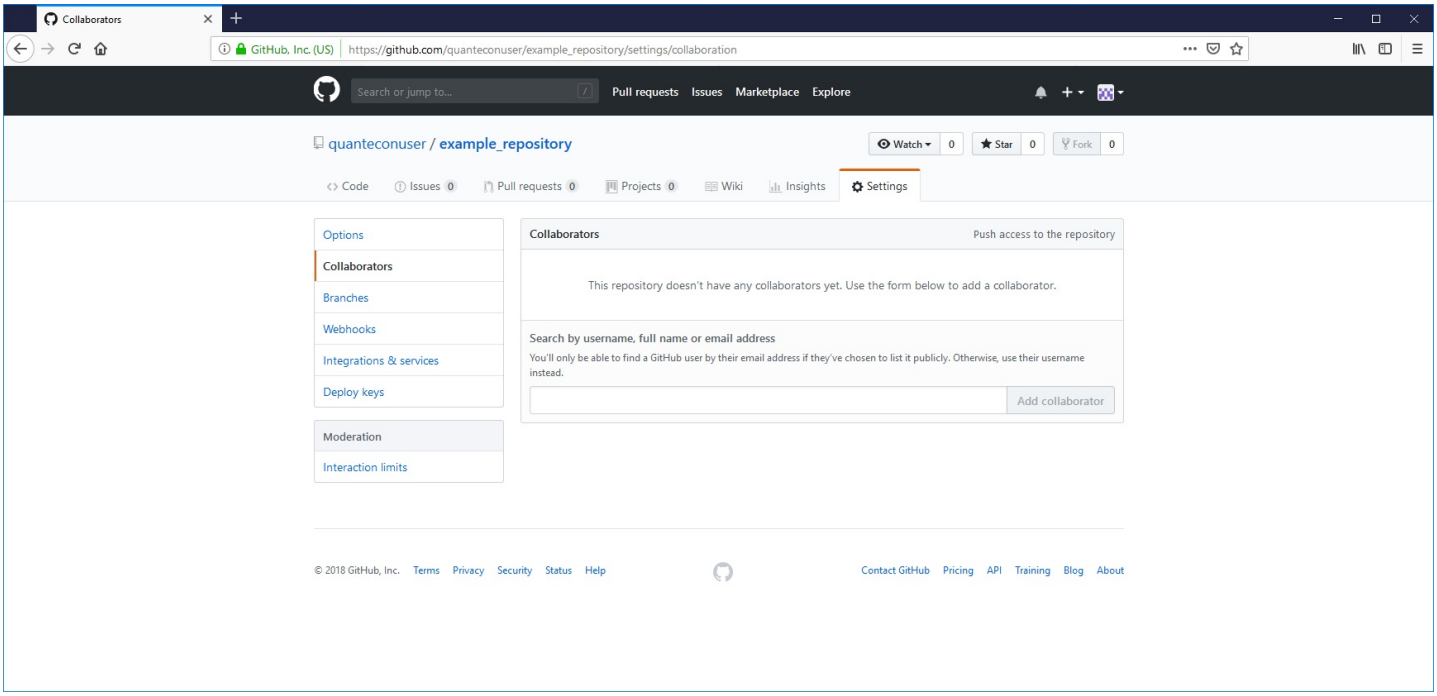


Collaborative Work

Adding Collaborators

First, let's add a collaborator to the `quanteconuser/example_repository` lecture we created earlier

We can do this by clicking "settings => collaborators," as follows

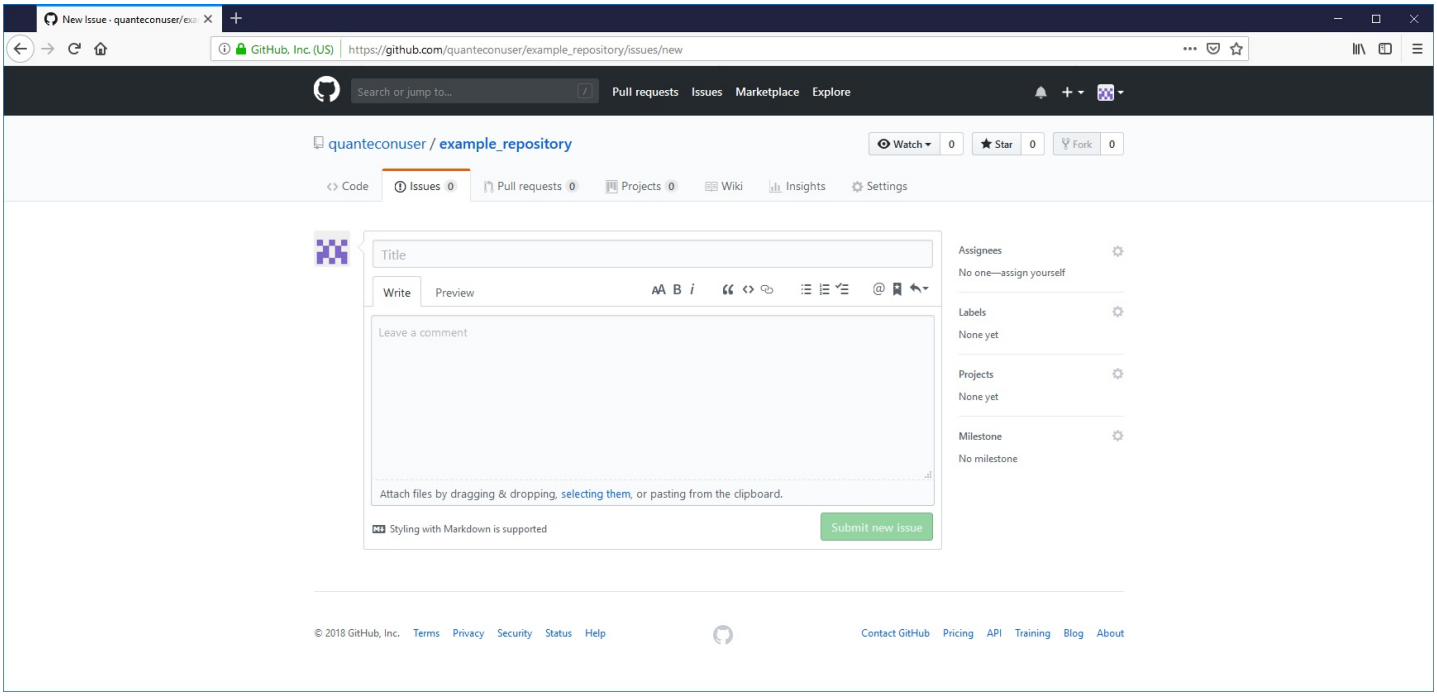


Project Management

GitHub's website also comes with project management tools to coordinate work between people

The main one is an issue, which we can create from the issues tab

You should see something like this

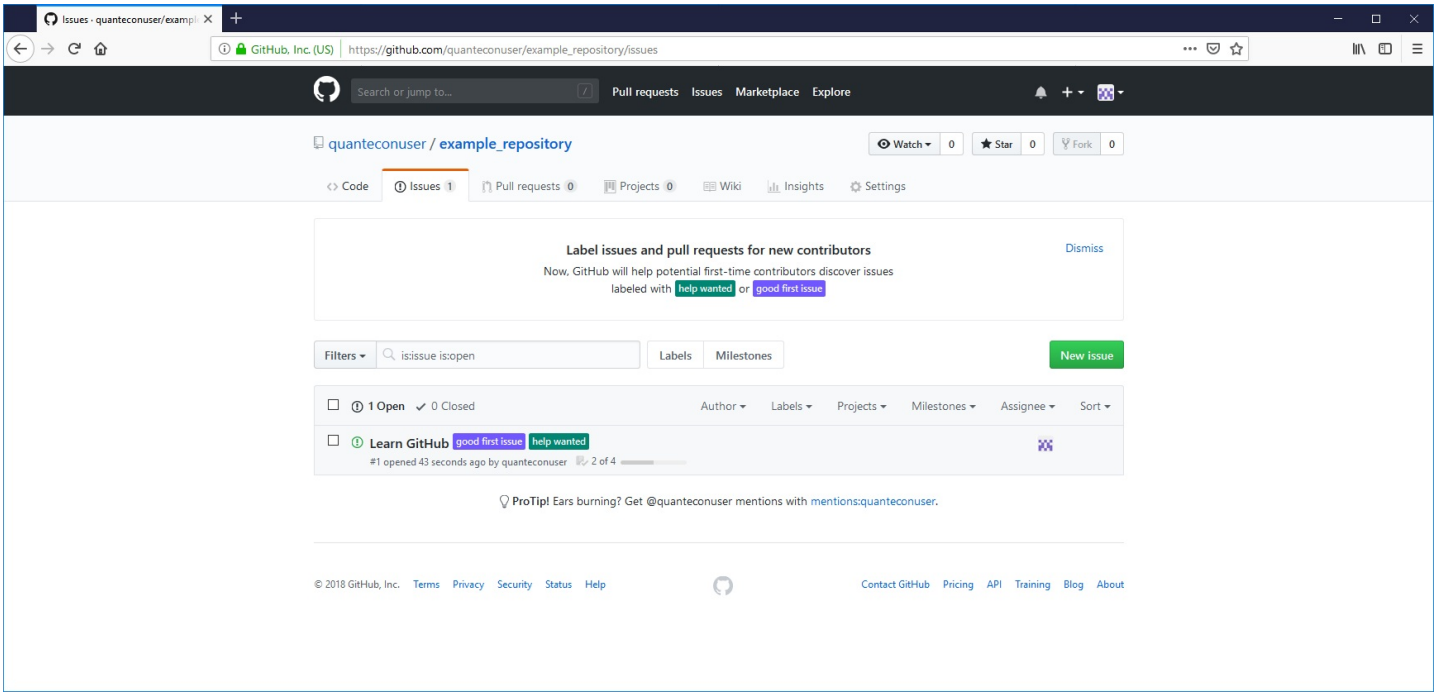


Let's unpack the different components

- The assignees dropdown lets you select people tasked to work on the issue
- The labels dropdown lets you tag the issue with labels visible from the issues page, such as "high priority" or "feature request"
- It's possible to tag other issues and collaborators (including in different repos) by linking to them in the comments – this is part of what's called GitHub-Flavored Markdown

For an example of an issue, see here

You can see open issues at a glance from the general issues tab

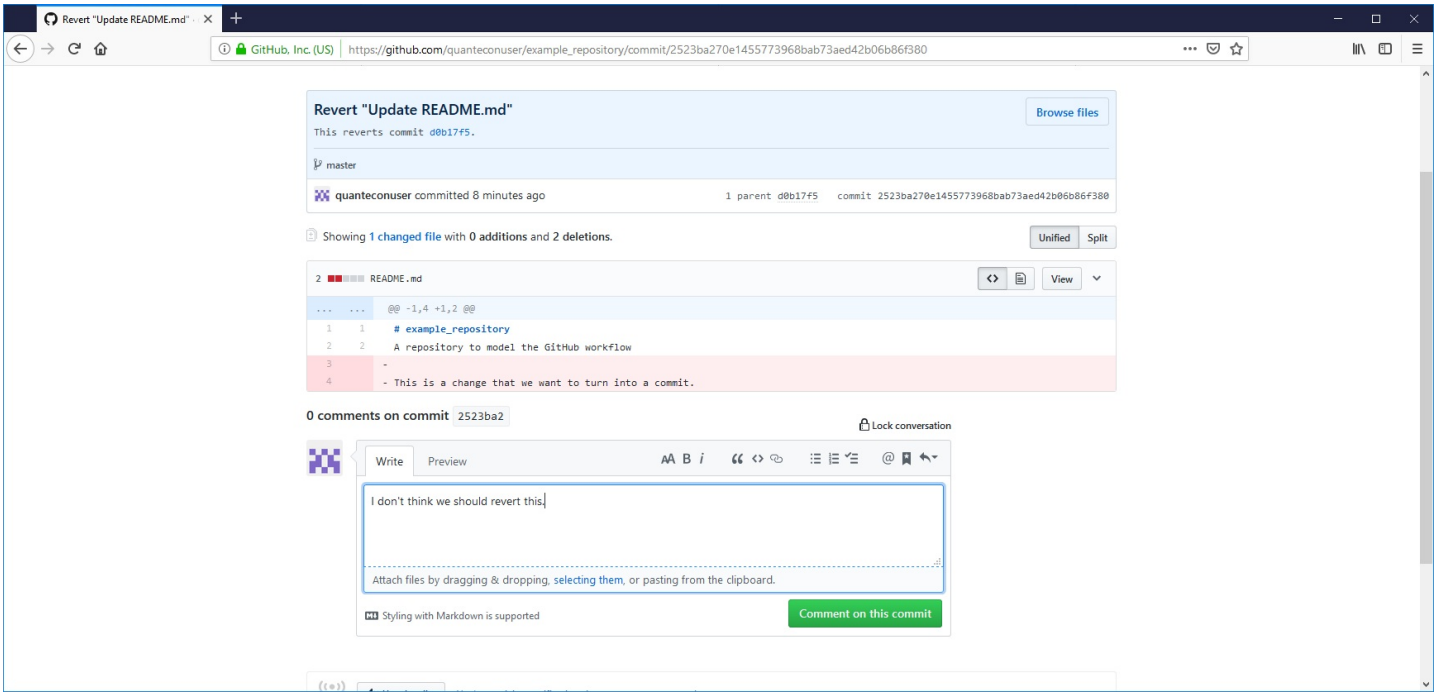


The checkboxes are common in GitHub to manage project tasks

Reviewing Code

There are a few different ways to review people's code in GitHub

- Whenever people push to a project you're working on, you'll receive an email notification
- You can also review individual line items or commits by opening commits in the difference view as above



Merge Conflicts

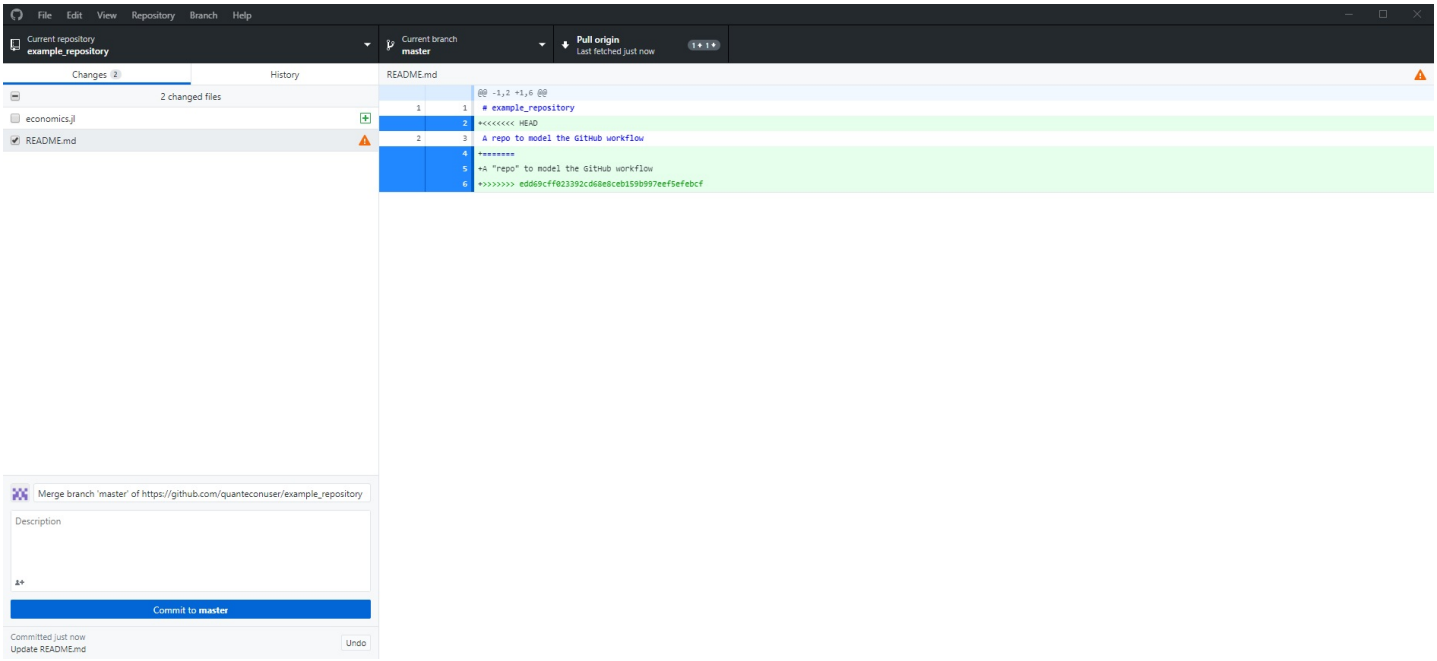
Any project management tool needs to figure out how to reconcile conflicting changes between people

In GitHub, this event is called a "merge conflict," and occurs whenever people make conflicting changes to the same line of code

Note that this means that two people touching the same file is OK, so long as the differences are compatible

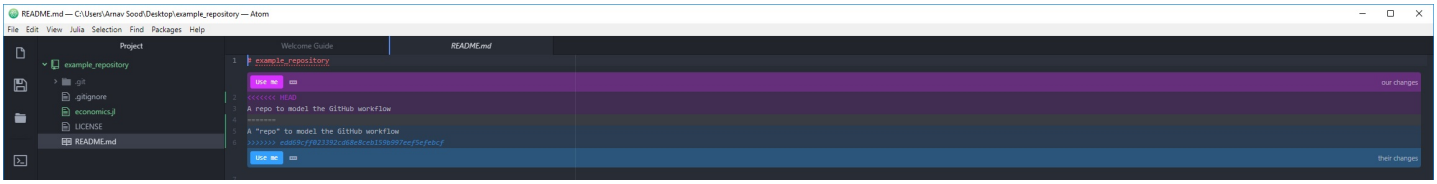
A common use case is when we try to push changes to the server, but someone else has pushed conflicting changes

GitHub will give us the following window



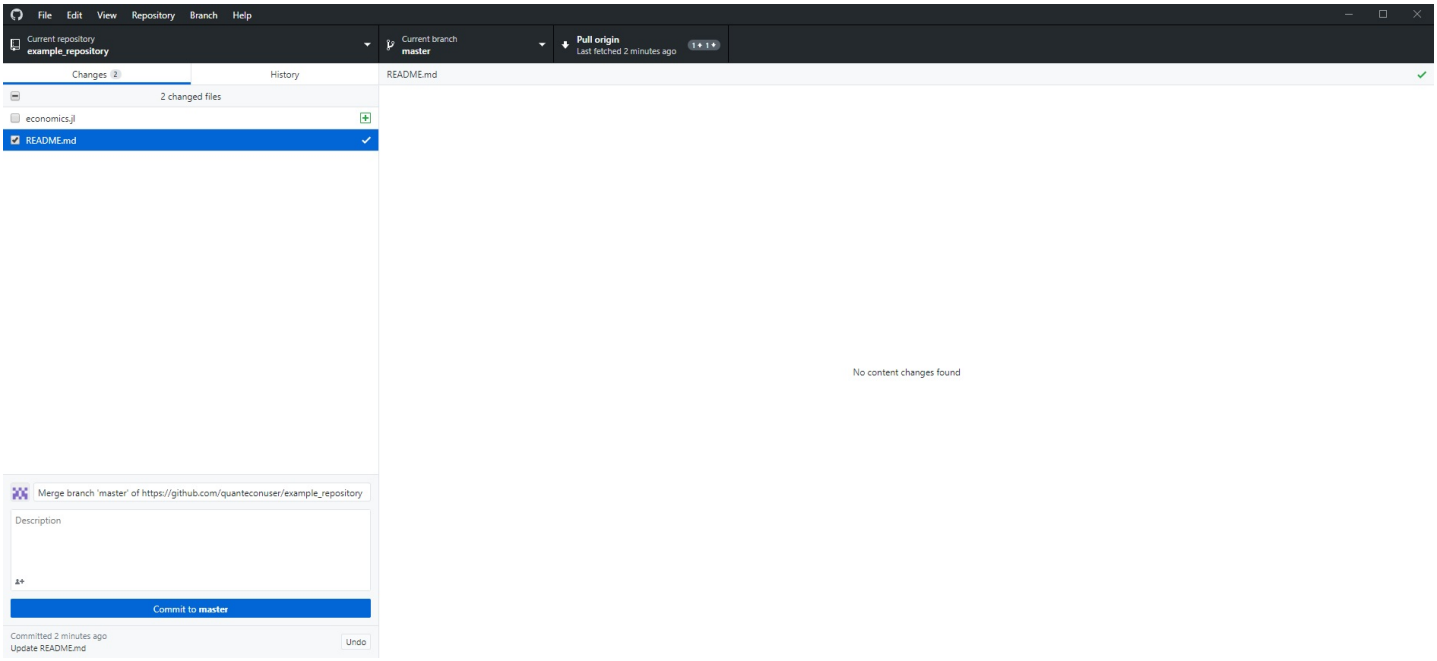
- The warning symbol next to the file indicates the existence of a merge conflict
- The viewer tries to show us the discrepancy (I changed the word repository to repo, but someone else tried to change it to “repo” with quotes)

To fix the conflict, we can go into a text editor (such as Atom)



Let’s say we click the first “use me” (to indicate that my changes should win out), and then save the file

Returning to GitHub Desktop gives us a pre-formed commit to accept



Clicking “commit to master” will let us push and pull from the server as normal

Collaboration via Pull Request

One of the defining features of GitHub is that it is the dominant platform for open source code, which anyone can access and use

However, while anyone can make a copy of the source code, not everyone has access to modify the particular version stored on GitHub

A maintainer (i.e. someone with “write” access to directly modify a repository) might consider different contributions and “merge” the changes into the main repository if the changes meet their criteria

A pull request (“PR”) allows **any** outsiders to suggest changes to open source repositories

A PR requests the project maintainer to merge (“pull”) changes you’ve worked on into their repository

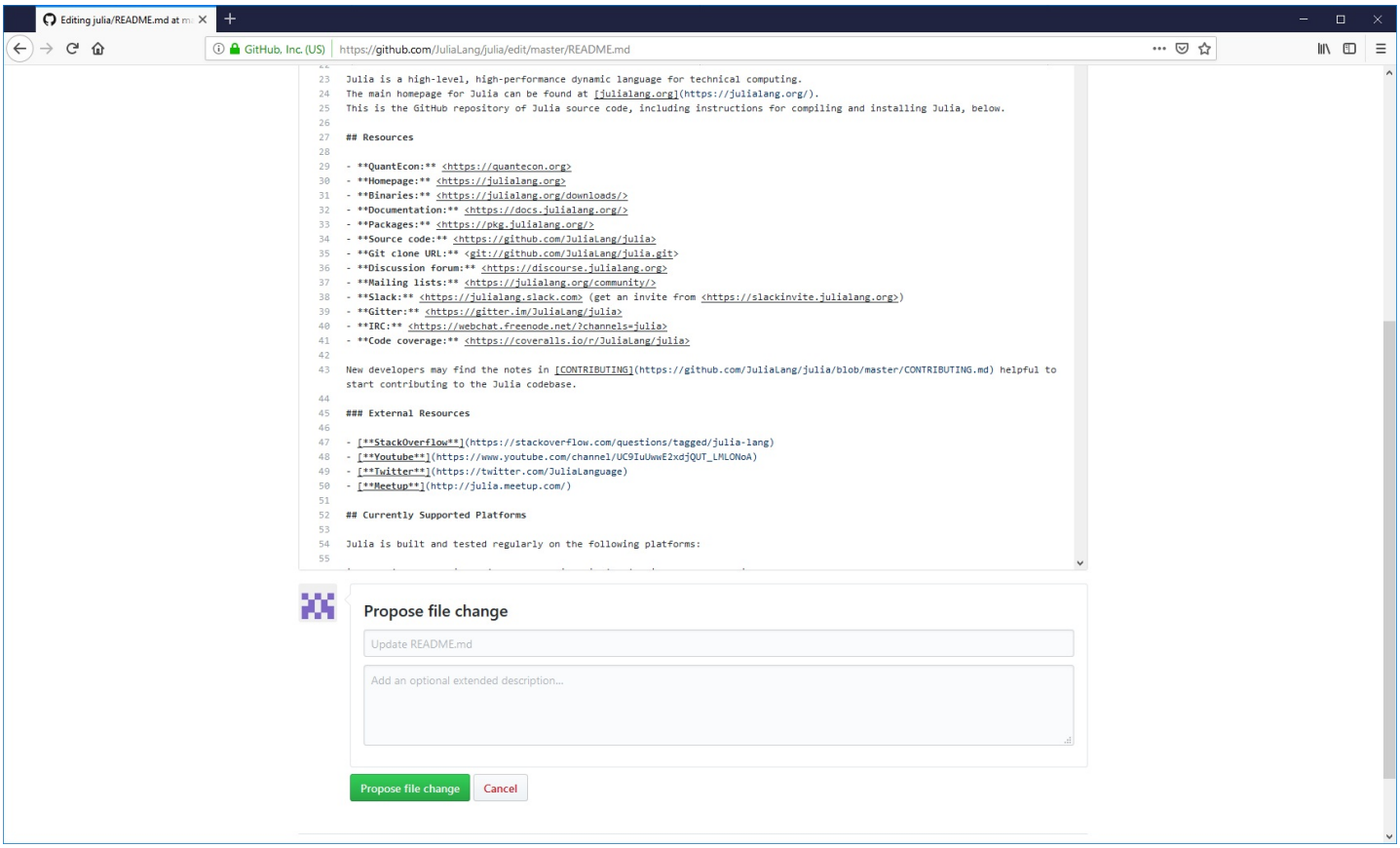
There are a few different workflows for creating and handling PRs, which we’ll walk through below

Note: If the changes are for a Julia Package, you will need to follow a different workflow – described in the testing lecture

Quick Fixes

GitHub’s website provides an online editor for quick and dirty changes, such as fixing typos in documentation

To use it, open a file in GitHub and click the small pencil to the upper right



Here, we’re trying to add the QuantEcon link to the Julia project’s `README` file

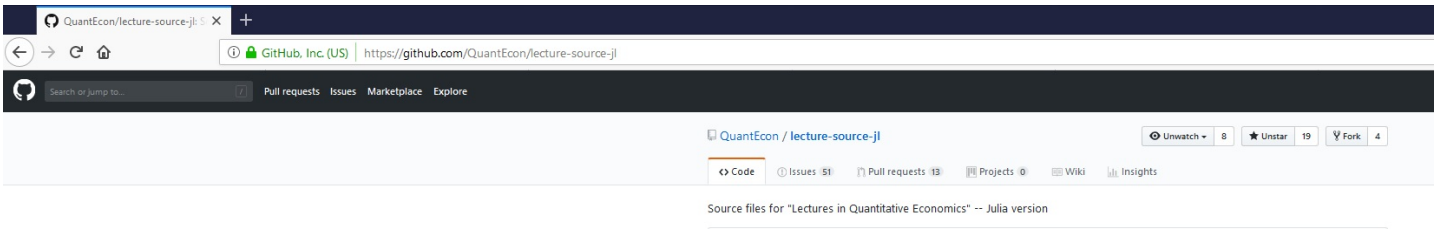
After making our changes, we can then describe and propose them for review by maintainers

But what if we want to make more in-depth changes?

No-Access Case

A common problem is when we don’t have write access (i.e. we can’t directly modify) the repo in question

In that case, click the “Fork” button that lives in the top-right of every repo’s main page

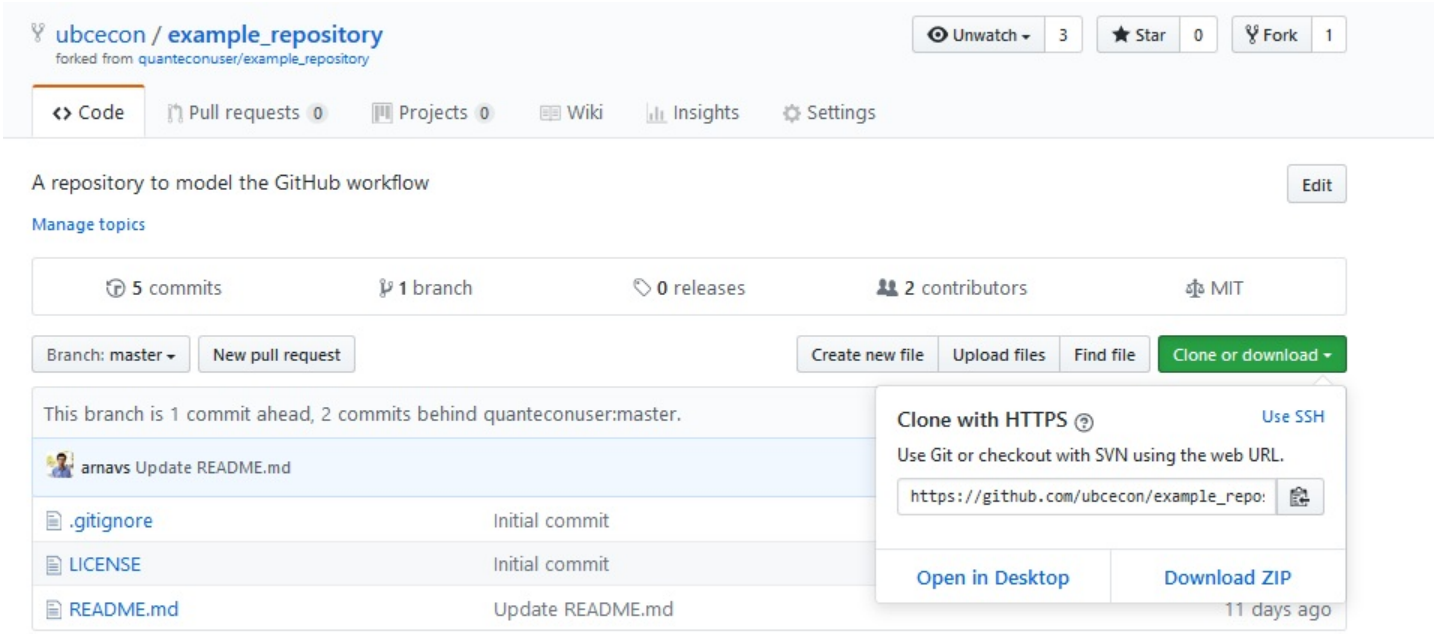


This will copy the repo into your own GitHub account

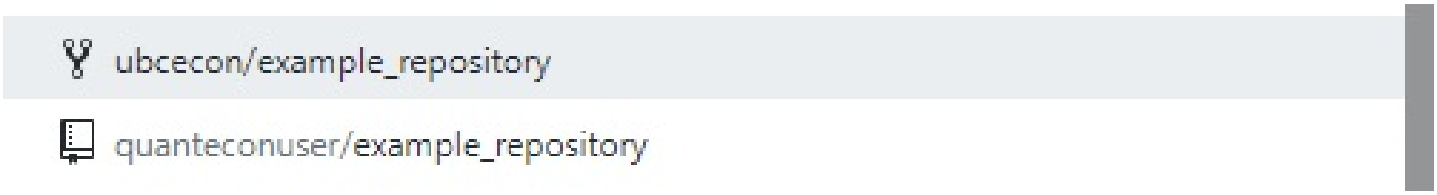
For example, this repo is a fork of our original git setup

Clone this fork to our desktop and work with it in exactly the same way as we would a repo we own (as the fork is in your account, you now have write access)

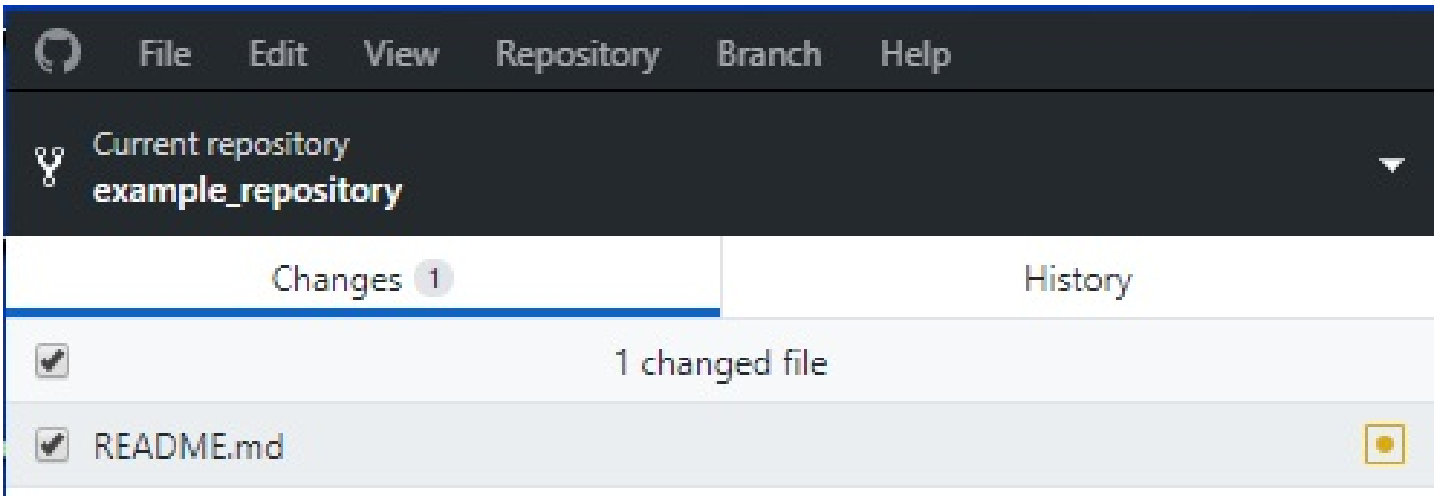
That is, click the “clone” button on our fork

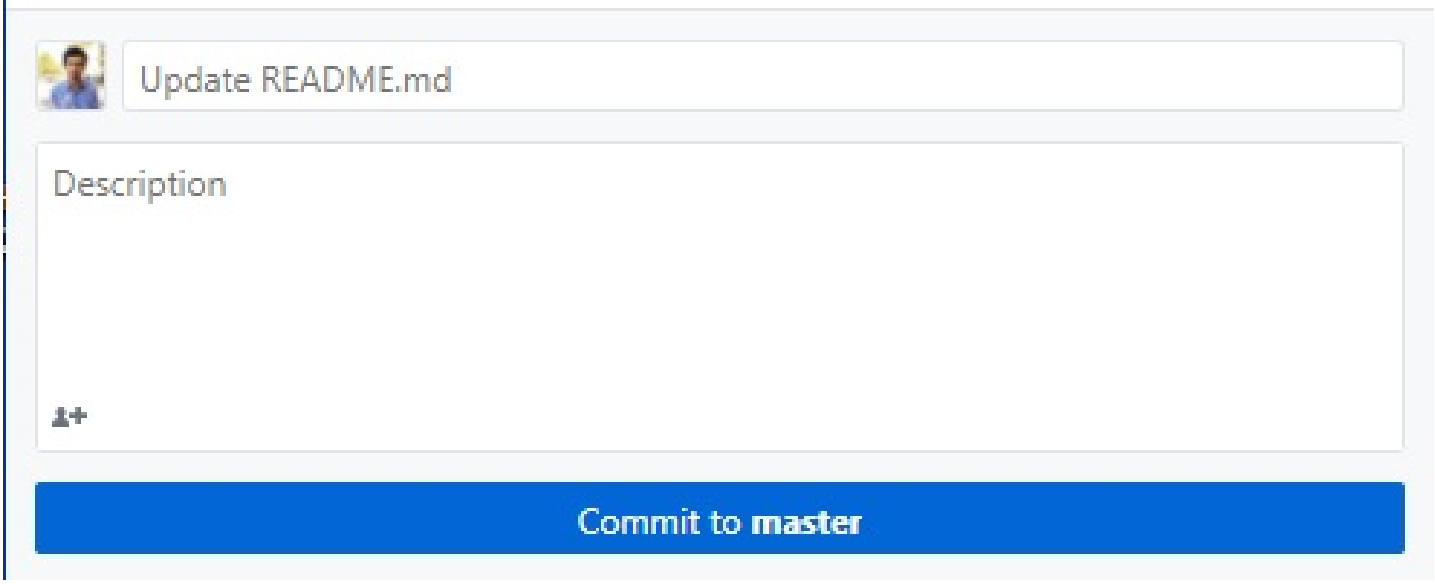


You’ll see a new repo with the same name but different URL in your GitHub Desktop repo list, along with a special icon to indicate that it’s a fork

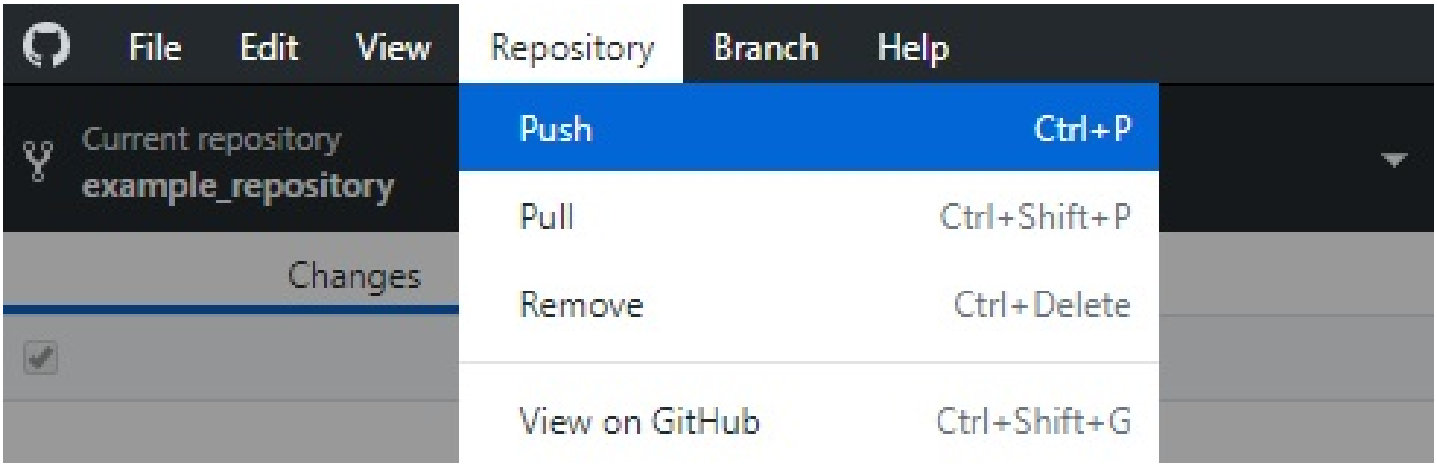


Commit some changes by selecting the files and writing a commit message

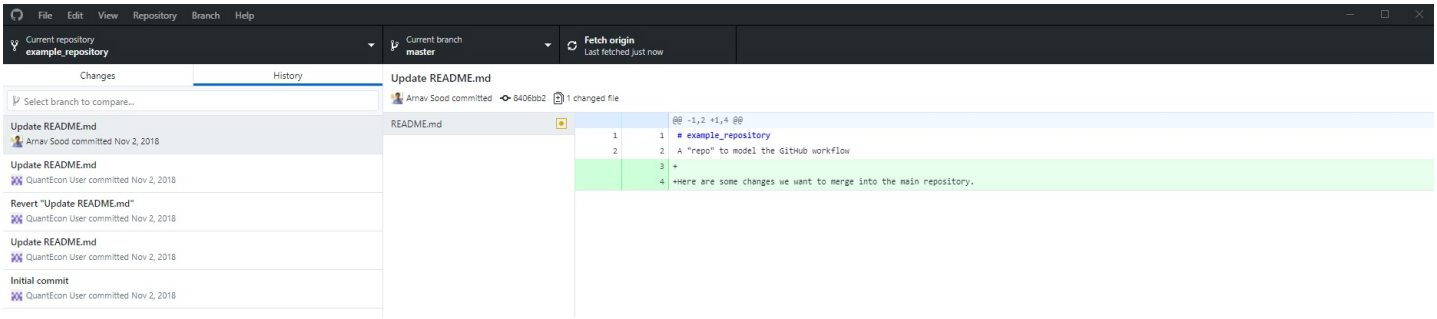




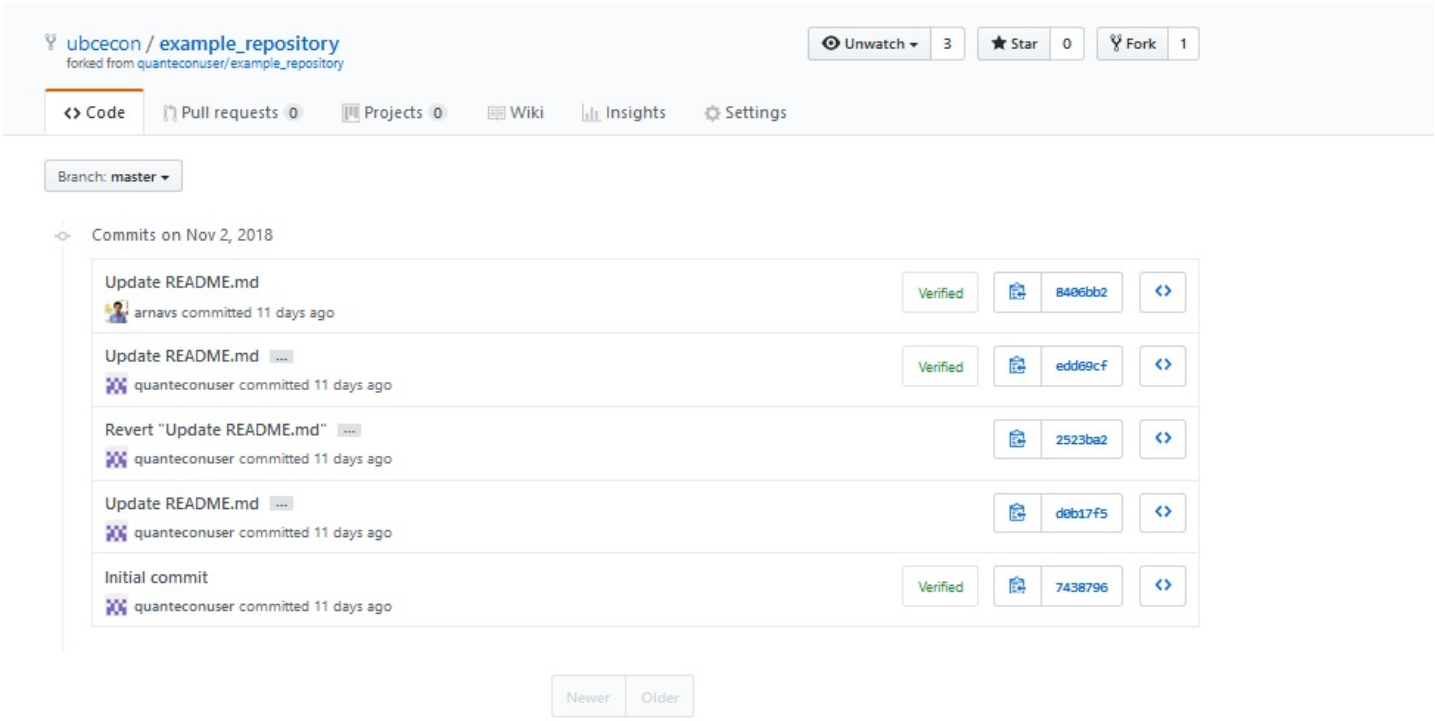
And push by using the dropdown



Below, for example, we've committed and pushed some changes to the fork that we want to upstream into the main repo

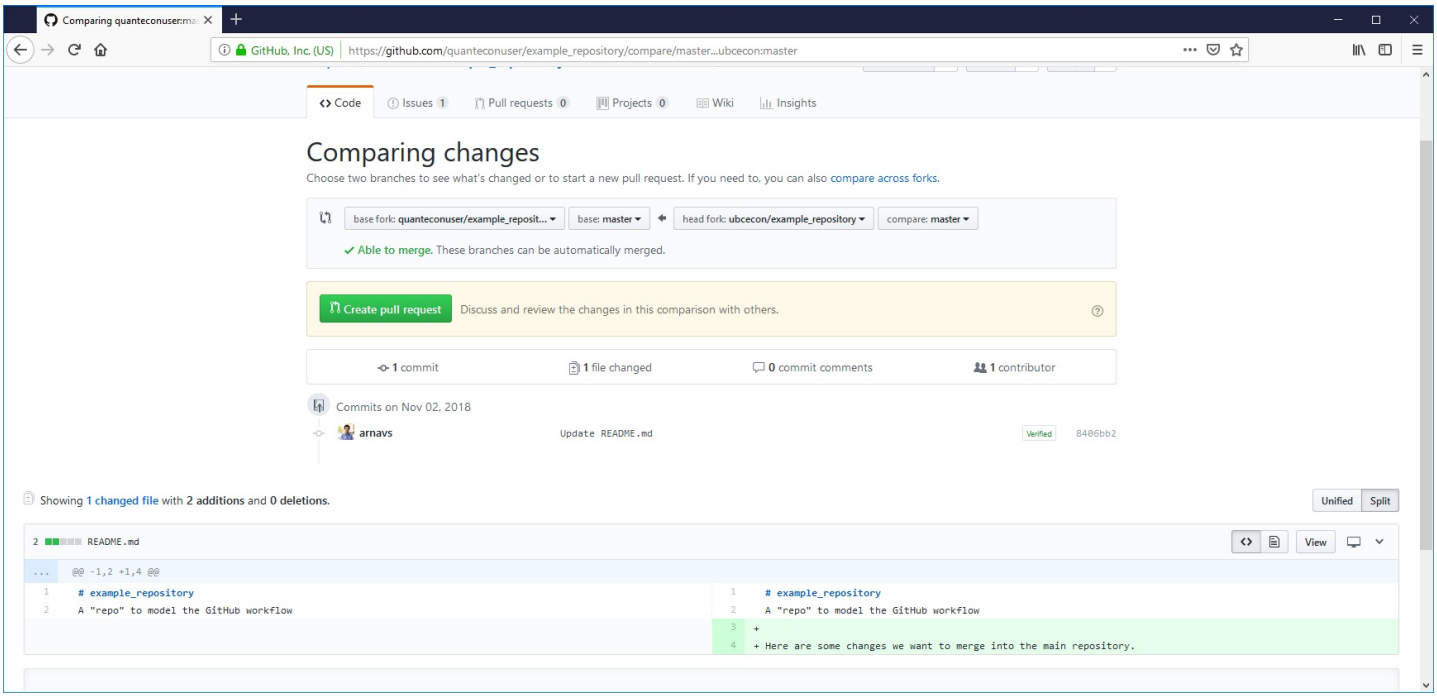


We should make confirm that these changes are on the server (which we can get to by going to the fork and clicking “commits”)



Next, go to the pull requests menu and click “New Pull Request”

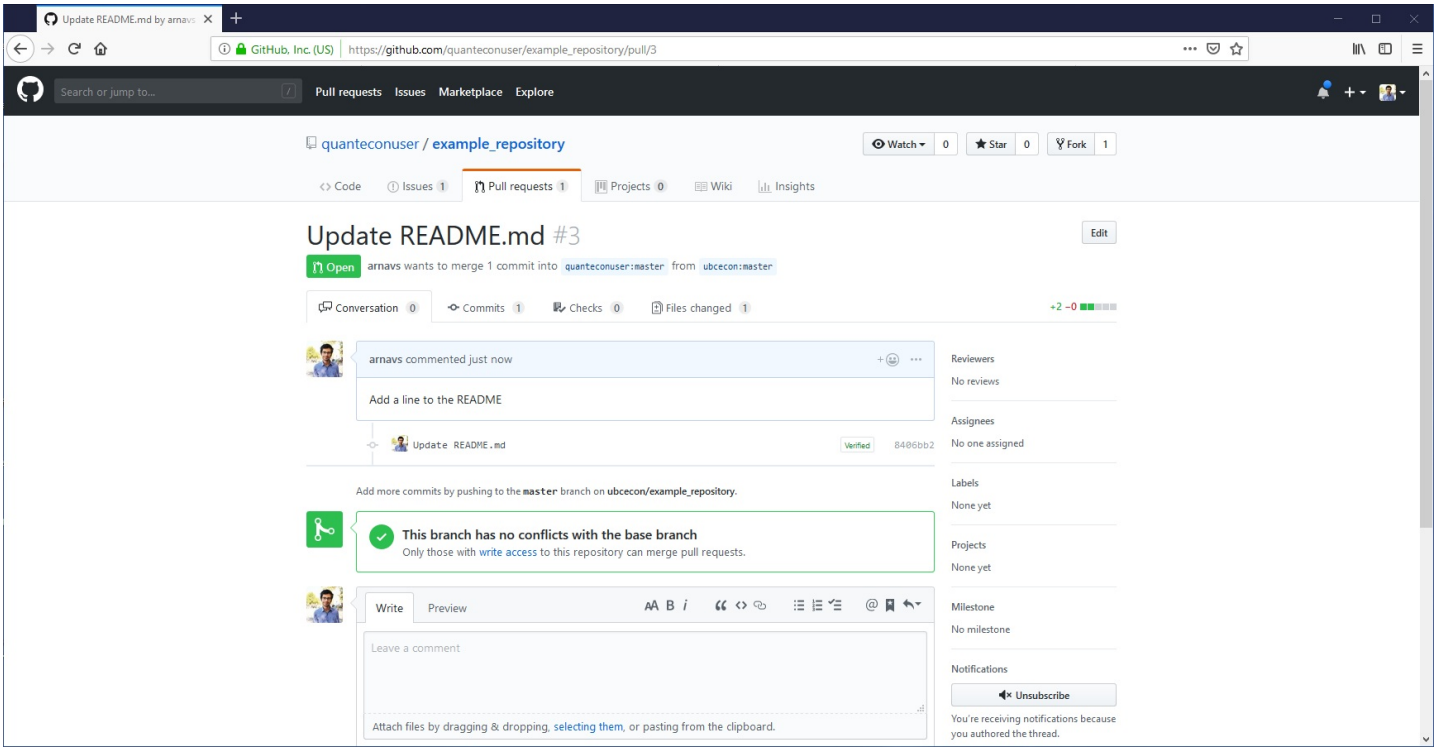
You’ll see something like this



This gives us a quick overview of the commits we want to merge in, as well as the overall differences

Hit create and then click through the following form

This opens a page like this on the main repo



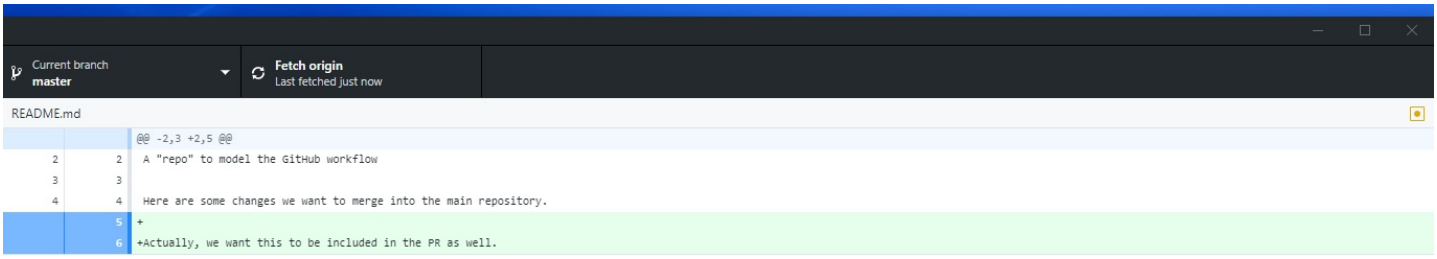
The key pieces are

- A list of the commits we're proposing
- A list of reviewers, who can approve or modify our changes
- Labels, Markdown space, assignees, and the ability to tag other git issues and PRs, just as with issues

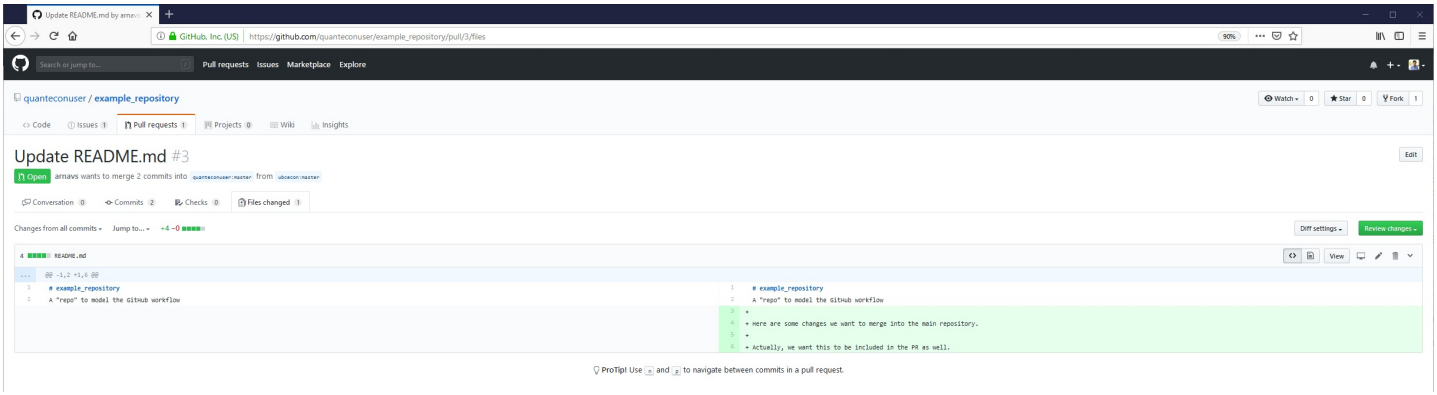
Here's an example pull request

To edit a PR, simply push changes to the fork you cloned to your desktop

For example, let's say we commit a new change to the README after we create the PR



After pushing to the server, the change is reflected on the PR page



That is, creating a pull request is not like bundling up your changes and delivering them, but rather like opening an ongoing connection between two repositories, that is only severed when the PR is closed or merged

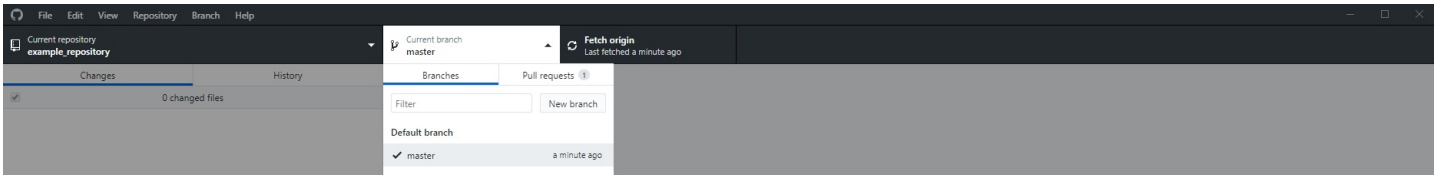
Write Access Case

As you become more familiar with GitHub, and work on larger projects, you will find yourself making PRs even when it isn't strictly required

If you are a maintainer of the repo (e.g. you created it or are a collaborator) then you don't need to create a fork, but will rather work with a git branch

Branches in git represent parallel development streams (i.e., sequences of commits) that the PR is trying to merge

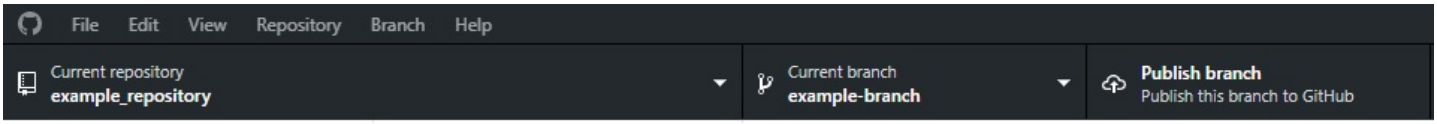
First, load the repo in GitHub Desktop and use the branch dropdown



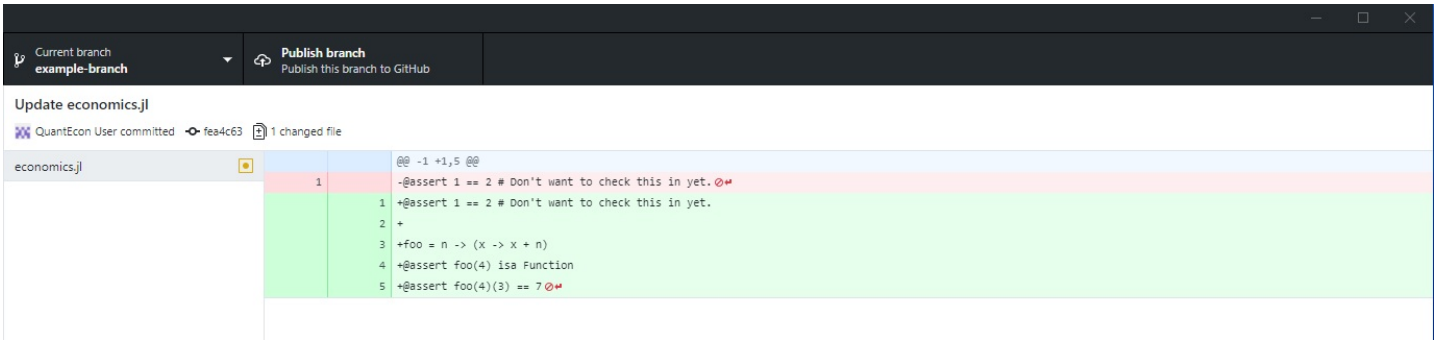
Click "New Branch" and choose an instructive name (make sure there are no spaces or special characters)

This will "check out" a new branch with the same history as the old one (but new commits will be added only to this branch)

We can see the active branch in the top dropdown

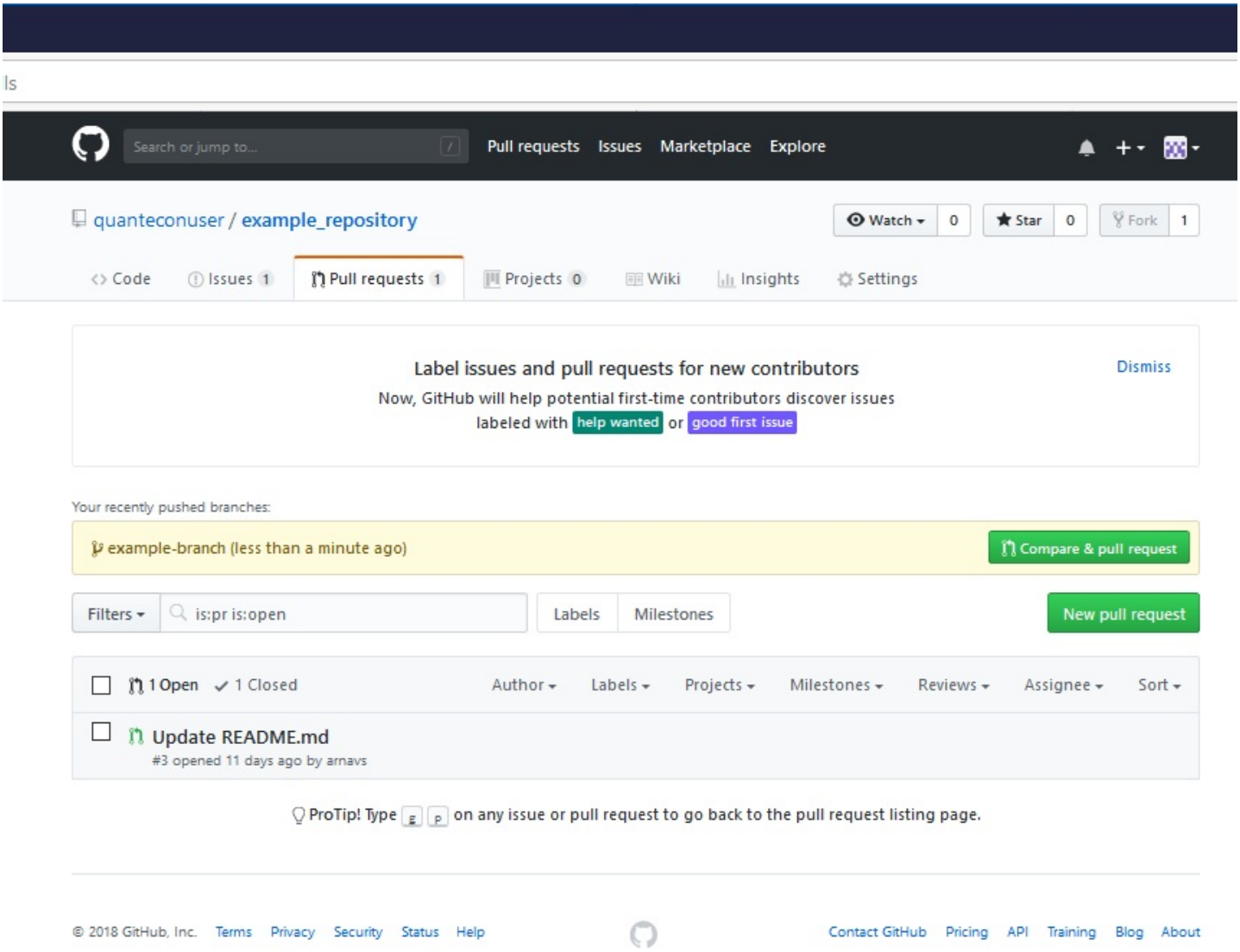


For example, let's say we add some stuff to the Julia code file and commit it



To put this branch (with changes) on the server, we simply need to click "Publish Branch"

Navigating to the repo page, we will see a suggestion about a new branch



At which point the process of creating a PR is identical to the previous case

Julia Package Case

One special case is when the repo in question is actually a Julia project or package

We cover that (along with package workflow in general) in the testing lecture

Additional Resources and Troubleshooting

You may want to go beyond the scope of this tutorial when working with GitHub

For example, perhaps you run into a bug, or you're working with a setup that doesn't have GitHub Desktop installed

Here are some resources to help

- Kate Hudson's excellent git flight rules, which is a near-exhaustive list of situations you could encounter, and command-line fixes
- The GitHub Learning Lab, an interactive sandbox environment for git
- The docs for forking on GitHub Desktop and the GitHub Website

Command-Line Basics

Git also comes with a set of command-line tools

They're optional, but many people like using them

Furthermore, in some environments (e.g. JupyterHub installations) you may only have access to the command line

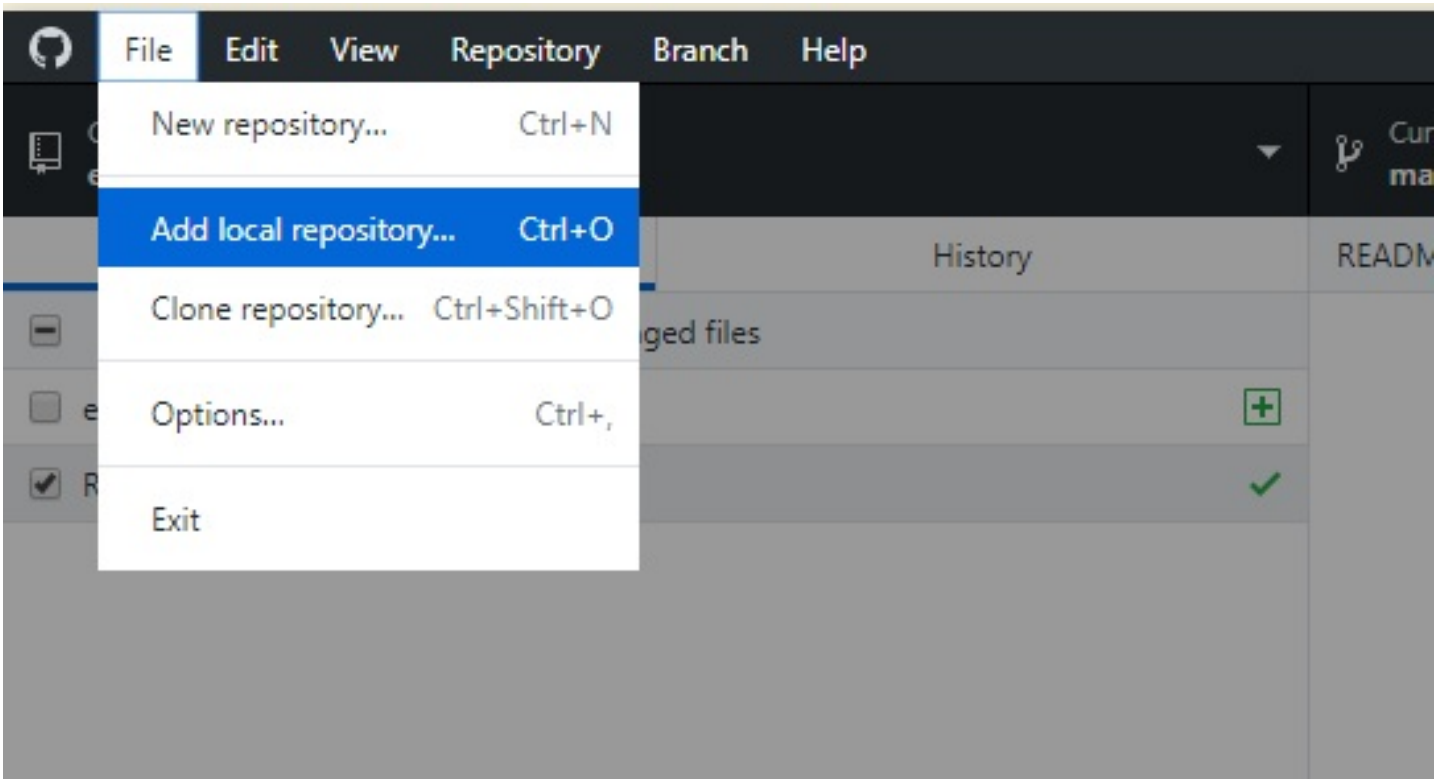
- On Windows, downloading `git` will have installed a program called `git bash`, which installs these tools along with a general Linux-style shell
- On Linux/MacOS, these tools are integrated into your usual terminal

To open the terminal in a directory, either right click and hit "open git bash" (in Windows), or use Linux commands like `cd` and `ls` to navigate

See here for a short introduction to the command line

As above, you can clone by grabbing the repo URL (say, GitHub's site-policy repo) and running `git clone https://github.com/github/site-policy.git`

This won't be connected to your GitHub Desktop, so you'd need to use it manually (`File => Add Local Repository`) or drag-and-drop from the file explorer onto the GitHub Desktop



From here, you can get the latest files on the server by `cd`-ing into the directory and running `git pull`

When you `pull` from the server, it will never overwrite your modified files, so it is impossible to lose local changes

Instead, to do a hard reset of all files and overwrite any of your local changes, you can run `git reset --hard origin/master`

Exercises

Exercise 1a

Follow the instructions to create a new repository for one of your GitHub accounts In this repository

- Take the code from one of your previous assignments, such as Newton's method in Introductory Examples (either as a `.jl` file or a Jupyter notebook)
- Put in a `README.md` with some text
- Put in a `.gitignore` file, ignoring the Jupyter files `.ipynb_checkpoints` and the project files, `.projects`

Exercise 1b

Pair-up with another student who has done Exercise 1a and find out their GitHub ID, and each do the following

- Add the GitHub ID as a collaborators on your repository
- Clone the repositories to your local desktop

- Assign each other an issue
- Submit a commit from GitHub Desktop which references the issue by number
- Comment on the commits
- Ensure you can run their code without any modifications

Exercise 1c

Pair-wise with the results of Exercise 1b examine a merge-conflict by editing the `README.md` file for your repository that you have both setup as collaborators

Start by ensuring there are multiple lines in the file so that some changes may have conflicts, and some may not

- Clone the repository to your local desktops
- Modify **different** lines of code in the file and both commit and push to the server (prior to pulling from each other)–and see how it merges things "automatically"
- Modify **the same** line of code in the file, and deal with the merge conflict

Exercise 2a

Just using GitHub's web interface, submit a Pull Request for a simple change of documentation to a public repository

The easiest may be to submit a PR for a typo in the source repository for these notes, i.e. `https://github.com/QuantEcon/lecture-source-jl`

Note: The source for that repository is in `.rst` files, but you should be able to find spelling mistakes/etc. without much effort

Exercise 2b

Following the instructions for forking and cloning a public repository to your local desktop, submit a Pull Request to a public repository

Again, you could submit it for a typo in the source repository for these notes, i.e. `https://github.com/QuantEcon/lecture-source-jl`, but you are also encouraged to instead look for a small change that could help the documentation in another repository.

If you are ambitious, then go to the Exercise Solutions for one of the Exercises in these lecture notes and submit a PR for your own modified version (if you think it is an improvement!)