Department for Education

DfE Statistics Development Team Workshops

Coding RAP using R

Contents

Introduction

We've prepared this walkthrough guide for statistics publication teams as an introduction to the ways in which coding in R can be used for Reproducible Analytical Pipelines (RAPs), creating functions for typical tasks that teams may come across. The guide is intended to be step-by-step, building up from the very basics. The plan is to work through this in groups of 3-ish with access to experienced R users for support. If it starts too basic for your level, then just go through at your own/your group's pace as you see fit. By no means can we cover everything in this walkthrough, so please see it as a prompt to ask follow-up questions as you're working through on anything related to R, RAP and coding in general.

What is a RAP?

RAP stands for Reproducible Analytical Pipeline. The full words still hide the true meaning behind buzzwords and jargon though. What it actually means is using automation to our advantage when analysing data, and this is as simple as writing code such as an R script that we can click a button to execute and do the job for us.

Using R (the coding language) really helps us to put the R in RAP ('reproducible'). Ask yourself, if someone else picked up your work, could they easily reproduce your exact outputs? And when the time comes around to update your analysis with new data, how easy is it for you to reproduce the analysis you need? In an ideal RAP, it would be as simple as plugging the new data in and clicking 'go', with no need to manually scroll through multiple scripts updating the year in every file name or the variable name that's changed from using _ to -.

Pre-workshop requirements

Technical requirements

First of all, make sure to bring your laptop. This is going to be interactive and require you to do some coding.

Preferably before coming along, you'll need to go through the following list of things you'll need to make sure are set up on your DfE laptop:

- Set up an Azure Dev Ops Basic account (not a Stakeholder account) at the DfE Service Portal; Either:
- Install git on your laptop: https://git-scm.com/downloads;
- Install R-Studio on your machine: Download **R for Windows (x64)** and **RStudio** from the Software Centre on your DfE laptop.

Or:

- If you're on EDAP and used to using R/R-Studio and/or git on there, feel free to just use that.

You'll also need to make sure that git is set up in the git/SVN pane of global options in R-Studio (found in the Tools drop down menu). Make sure the path to your git executable is entered in the git path box and git should automatically be integrated with R-Studio.

Figure 1: Enter the path to your git executable in the git path option box

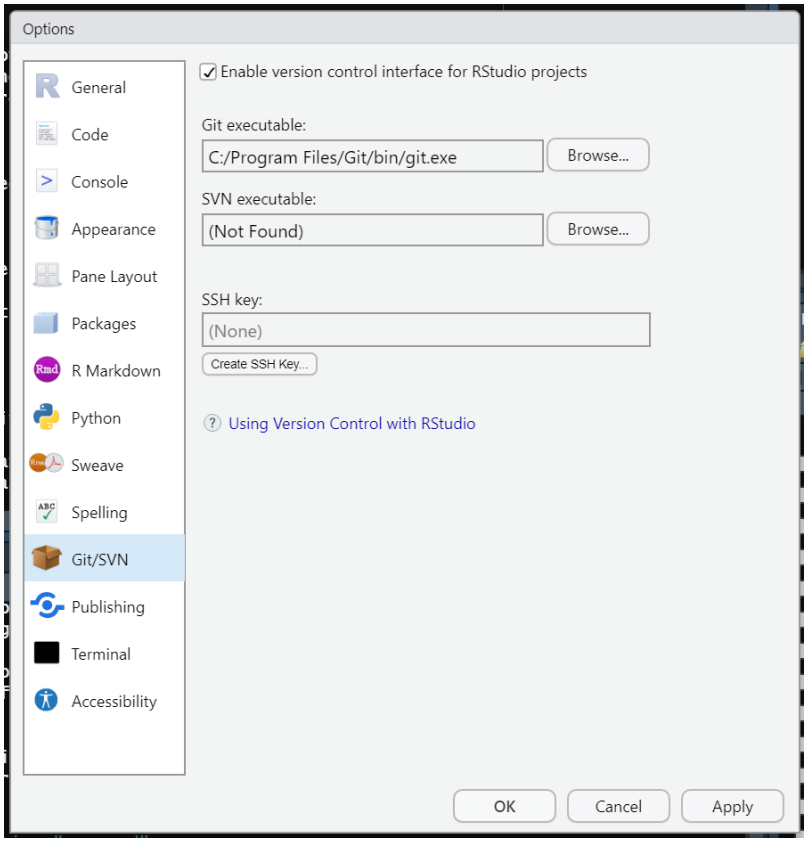
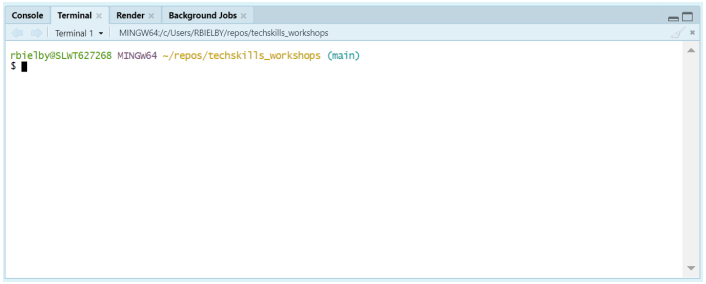


Figure 2: The ‘git BASH‘ terminal in R-Studio



Once you open a repository, you’ll get an extra panel, named ‘git’, in the top right pane of R-Studio and you’ll also be able to use git in the ‘Terminal’ tab at the bottom left (in the same place as the R console).

A useful thing here if you want to use git commands in the terminal is to switch the terminal from the default Windows Command Prompt to `git BASH`. You can do this in the Terminal tab of R-Studio’s global options - just select `git BASH` from the ‘New terminal opens with’ pull down menu. Click apply and then select the Terminal tab (next to the Console tab), click ‘Terminal 1’ and then select ‘New terminal’ from the drop down menu. You should see something similar to the terminal screenshot.

Working in teams

To get the most out of git and Dev Ops, you’re going to need to work in teams. We’re aiming for groups of 3. Some of the tasks we’ll work through will require just one of your team to perform, whilst others will require all of your team to perform them. If it’s not clear then ask and most importantly, communicate with each other about what you’re doing.

To help illustrate the challenges and benefits of git and Dev Ops and how to work collectively within the same space, all the groups will be working within the same repository. Each group will have their own working branch (already created) with the naming format `workshop_group_N`:

- `workshop_group_1`
- `workshop_group_2`
- ...

We’ll need to prefix branches and tasks within the repository with `grN_` and group N respectively (again switching the `N` for your group number).

By the end, you should get a good idea of how to utilize R for RAP processes, as well as how to collaborate using git!

Getting started . . .

Basics. . .

Working collaboratively with git...

Git only really makes proper sense once multiple people start working on a project collaboratively. Solo working, git is useful for version control and syncing your work to a remote repository site like Dev Ops and GitHub, but may not feel like it offers all that much more beyond that. Once we start working collaboratively however, the benefits of using git (alongside GitHub or Dev Ops) become more apparent. We'll now look further into this with some worked examples.

Branches and splitting tasks

Task management

One useful management tool that we can use from Dev Ops is the *Boards* area. Here we can create individual tasks, assign them to team member and then create new **branches** from those tasks. You can think of **branches** as self contained copies of the repository that can contain complementary or conflicting differences with all other **branches** in the repository. These allow you to work on different multiple tasks on your code independently of any other changes you might be making. Bringing these different **branches** or tasks together is then managed using **merges** or **pull requests** (PRs).

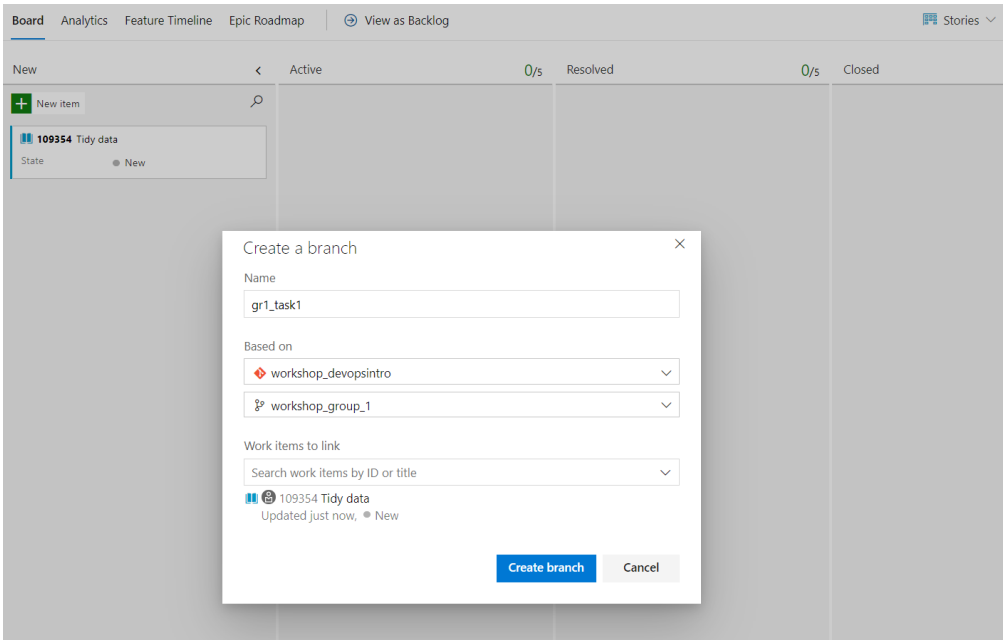
We'll demonstrate this by performing 3 related tasks on 3 different branches. Each task should be done by only one of your group, so split the following 3 tasks between your group and each follow the relevant instructions in the subsections below:

- 1a) Tidying the data
- 1b) Creating the wide data plot
- 1c) Creating the tidy data plot

Once you've decided who's doing what, each of you should jump to the relevant section below. And remember that you're not working in independent silos here, what you do can impact what other people are doing so communication needs to happen along the way.

Tidying the data Start the task by going to your Dev Ops board and click on the options for the Tidying data task. Select **Create new branch** from the drop down menu that appears over the task. You'll get a pop-up dialogue box with some options about

your new branch. Give the new branch a name (e.g. `grN_task1`), make sure it's based on your group's branch (`workshop_group_N`) in the `workshop_devopsintro` repo and then click **Create branch**.



You'll now have a new branch in your remote repo that's identical to your groups working branch. To access that branch in your local repo, you just need to perform a pull (i.e. `git pull` in the `bash` terminal or the down arrow in the R-Studio git panel) and then switch branches (`git switch grN_task1` in `bash` or select from the drop down menu in the git panel).

Now to make the edits. Copy and paste the following code into the script `R/utils.R`:

```
tidy_subject_timeseries <- function(dfin){
  # Pivot long and then update the string values in the new filter column.
  dftidied <- dfin  %>%
    pivot_longer(!c(time_period,time_identifier,geographic_level,
                    country_code,country_name,version,characteristic_gender,
                    subject,entries),
                 names_to="level",
                 values_to="percentage_pupils")
  colnames(dftidied) <- gsub("characteristic_","",colnames(dftidied))
  return(dftidied)
}
```

And then go back to `main.R` and add the lines:

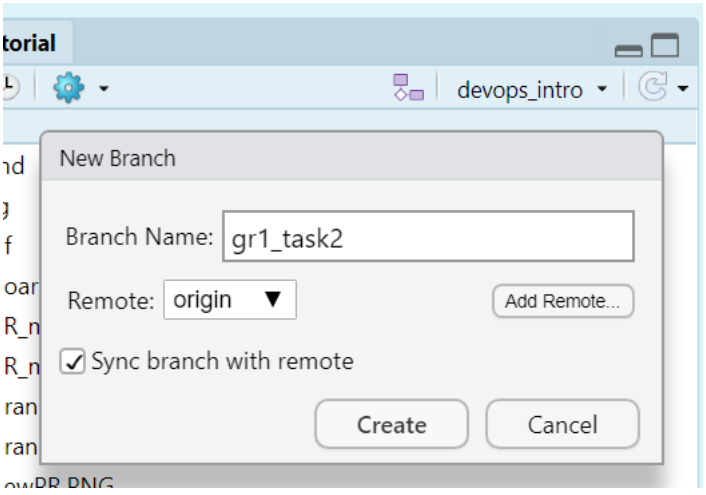
```
library(tidyr)
library(dplyr)
source('R/utils.R')
dfKS4tidied <- tidy_subject_timeseries(dfKS4)
```

At this point you could try sourcing `main.R` in the R console and that should create the data frame `dftidied` (and hopefully not produce any errors!).

Once you're happy, then run another `add/commit/push` cycle and flag to your team that you've finished the code to read in the data. Then scroll down this guide to the merging and pull requests section.

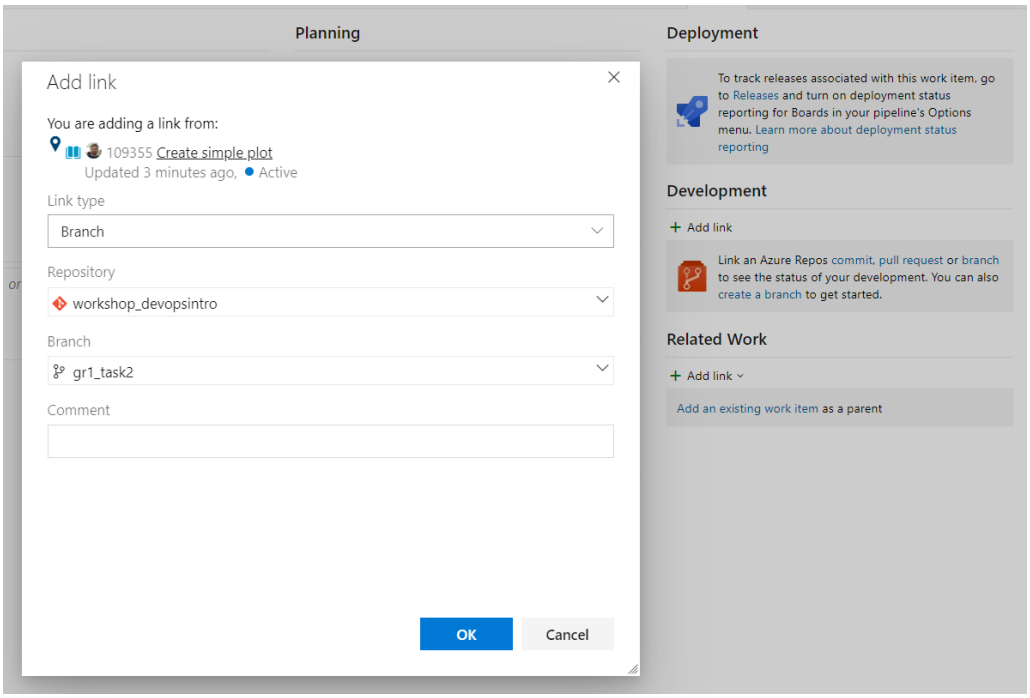
Creating the wide data plot Whilst the first task adds in some data, reads it in and does some processing, this task builds a quick chart based on the data.

Create a new branch within R-Studio. To do this, first make sure that you're in your groups branch (i.e. `workshop_group_N`) and then you can either a) use the command `git checkout -b grN_task2` (changing the N to your group number) and push to the remote (`git push`) or click the purple new branch button in the R-Studio git panel (see the image below).



We want to track this branch with the associated task in Dev Ops Boards, so go to the card you made for task 2 on your group's board. Move it to the **Active** column and then open up the task to edit. On the right hand side of the dialogue box, you can link your

branch to this task under **Development**. Click **Add link** and in the next dialogue box find and select your new branch from the branch drop down menu (as shown in the screenshot). Click Ok to complete the link. Then you should see your branch listed under **Development** (note the option to create a Pull request, which you can use later on when we merge this branch in to the rest of the development).



Now to make the changes. Head back to R-Studio and add the following lines of code to `R/plots.R` in your local copy of the repository:

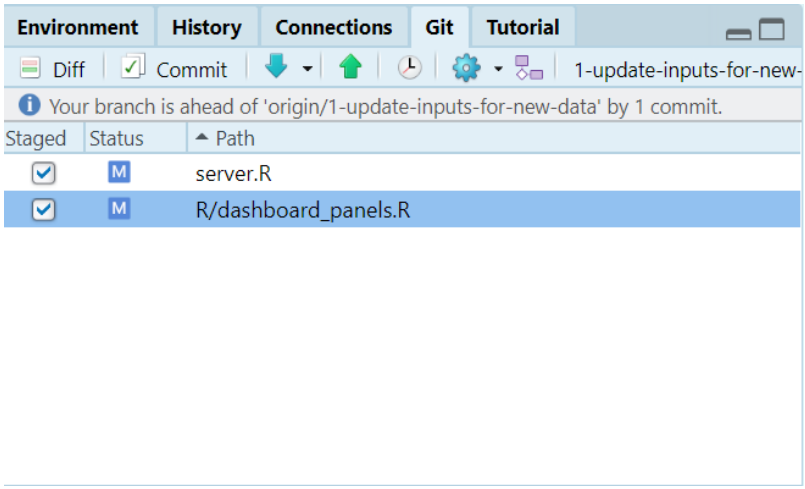
```
plot_ACrange <- function(df){
  dfplot <- df %>% filter(time_period>=201920,
                          !X94AstarC %in% c('z',':','x'),
                          grepl('Studies',subject)) %>%
    select(time_period,characteristic_gender,entries,subject,X94AstarC) %>%
    mutate(entries=as.numeric(entries)/1.e3,
           X94AstarC=as.numeric(X94AstarC))
  df1 <- dfplot %>% filter(time_period==202021,characteristic_gender=='Total')
  plot(df1$entries,df1$X94AstarC)
}
```

And the following to `main.R`:

```
library(dplyr)
source('R/plots.R')
plot_ACrange(dfKS4)
```

And that should be it for this task. All that's left is to commit and push your changes. If you've got a preferred way already to perform commits, then go for it. If not then let's use the RStudio git panel.

Figure 3: Staging files in the RStudio git panel.



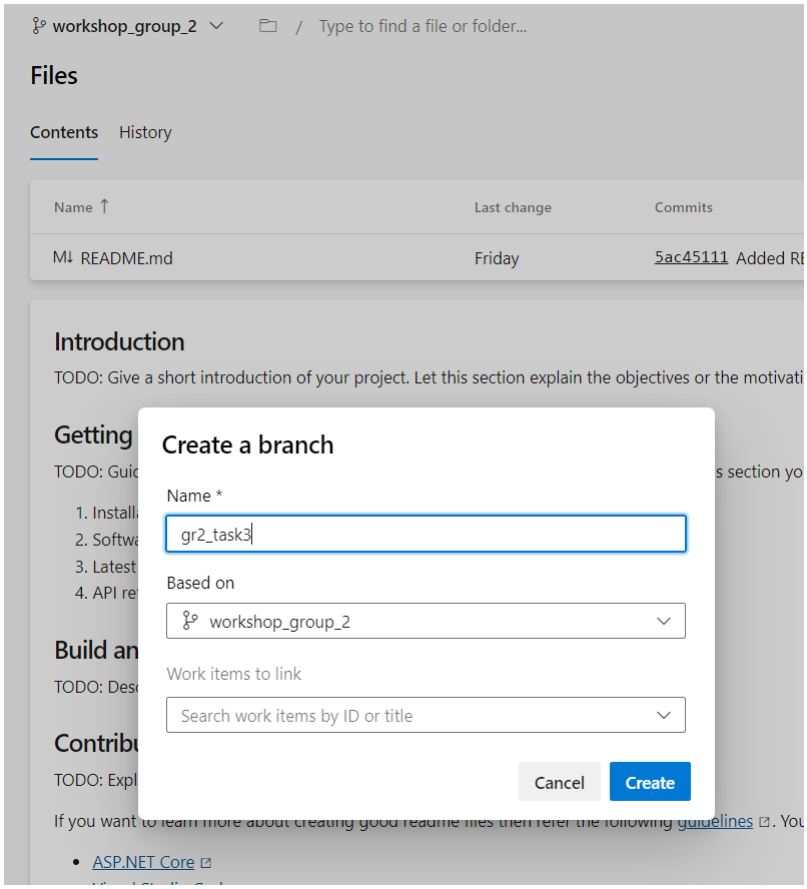
Firstly click on the git tab in the top right of RStudio to show the git panel (see the screenshot below). Next click the tickboxes next to the files with changes (i.e. these should be server.R and R/dashboards_panels.R) to **stage** (aka **add**) the files. Now click **commit**, add a commit message in the relavent text box and then hit **commit** in the bottom right corner of the window.

Assuming that all went through without any issues, you can now press the green up arrow in the git panel to **push** your changes to the remote repository on Dev Ops

Flag to your team that you've finished the code to read in the data. Then scroll down this guide to the merging and pull requests section.

Creating the tidy data plot Start by creating a new branch in Dev Ops. Navigate to the files panel of the repo on Dev Ops and click the branch drop down menu. Select your groups working branch (`working_group_N`). Click the drop down again and now select **+ New branch**. You'll get a pop-up dialogue box that looks like the image below. Fill in a name for the new branch and make sure your groups working branch is selected in the

Based on selection box. You can also link your task to this new branch by selecting it in the **Work items to link** selection box. Once you've done that, quickly go to your group's board and have a look at the task 3 card. If you haven't done so already, drag and drop the card into the Active column (you should then see that you automatically get asigned to the task in Dev Ops).



Now head to R-Studio, perform a pull (`git pull` in the terminal or the green down arrow in the git panel) and then switch to your new branch.

Then go ahead and add the following lines of code to `R/plots.R` in your local copy of the repository:

```
plot_ACrange_tidy <- function(dftidy){
  df <- dftidy %>% filter(time_period>=201920,level=='X94AstarC',
                          !percentage_pupils %in% c('z',':','x'),
                          grepl('Studies',subject)) %>%
    mutate(time_period = as.character(time_period),
```

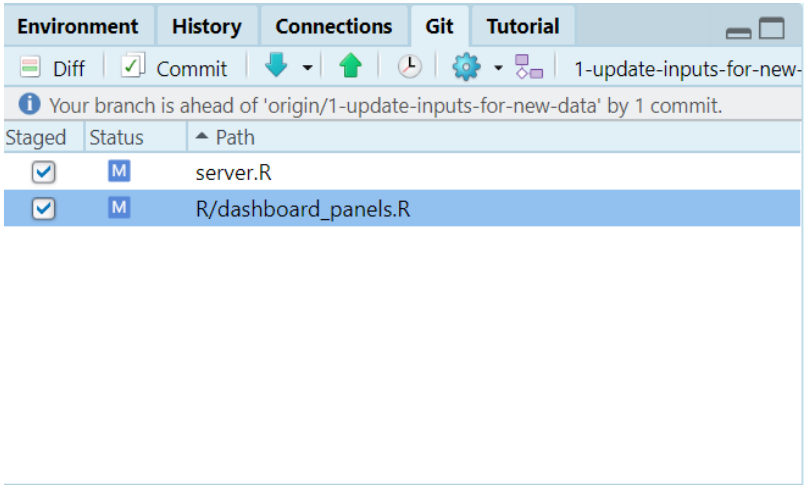
```
            entries=as.numeric(entries)/1.e3,
            percentage_pupils=as.numeric(percentage_pupils)) %>%
    mutate(achieved = as.numeric(percentage_pupils)/100.*entries)
  ggplot(df,aes(x = entries,
                y=percentage_pupils,group=time_period,color=subject)) +
    geom_point() +
    facet_grid(time_period ~ gender)
}
```

And the following to `main.R`:

```
library(dplyr)
library(ggplot2)
source('R/plots.R')
plot_ACrange_tidy(dfKS4tidied)
```

And that should be it for this task. All that's left is to commit and push your changes. If you've got a preferred way already to perform commits, then go for it. If not then let's use the RStudio git panel.

Figure 4: Staging files in the RStudio git panel.



Firstly click on the git tab in the top right of RStudio to show the git panel (see the screenshot below). Next click the tickboxes next to the files with changes (i.e. these should be server.R and R/dashboards_panels.R) to **stage** (aka **add**) the files. Now click **commit**, add a commit message in the relavent text box and then hit **commit** in the bottom right corner of the window.

Assuming that all went through without any issues, you can now press the green up arrow in the git panel to **push** your changes to the remote repository on GitHub.

Flag to your team that you've finished the code to read in the data. Then scroll down this guide to the merging and pull requests section.

Merging and pull requests

As part of using branches within git, you'll reach the point where you need to merge two branches together. This can be done with a git command from the `BASH` terminal, but usually it's more helpful to perform merges using a *Pull Request (PR)* in Dev Ops or GitHub. The difference between a merge and a pull request is basically that a pull request is a way to run a merge from Dev Ops or GitHub which provides some useful tracking tools to help you clearly understand and communicate what is happening as part of a given merge. Some key things the pull requests offer are:

- user documentation of changes;
- quick look diff/overview of changes made to files on the branch being merged;
- run automated tests;
- ability for collaborators to review your code;
- control of merge conflicts;
- final sign-off from collaborators;
- complete a merge.

We'll start though by trying a basic `git merge` from the terminal without these features offered by pull requests.

`git merge` (and a simple merge conflict)

As we've left things, the code for task 1 and task 2 both should work without errors. However, the code for task 3 (plotting from the tidied data frame) requires the code from task 1 (which produces the tided data frame) to be able to run. To get it running, we're going to merge the branch for task 1 into the branch for task 3. To do this, *one of your team* should switch into the branch for task 3 (e.g. `git switch task3`) and then run the following command:

```
git merge task1
```

This will attempt to merge the task1 branch into the task3 branch. However, this will produce a merge conflict and the merge will not complete. If you now look at the script `main.R`, it should now look something like the following:

```
dfKS4 <- read.csv('data/2021_subject_timeseries_data.csv')
colnames(dfKS4)[1] <- "time_period"

<<<<<<< HEAD
library(dplyr)
library(ggplot2)

source('R/plots.R')
plot_ACrange_tidy(dfKS4tidied)
=======
library(tidyr)
library(dplyr)
source('R/utils.R')
dfKS4tidied <- tidy_subject_timeseries(dfKS4)
>>>>>>> task1
```

A merge conflict happens when two concurrent changes have been made across different branches to the same bit of a file. Here we can see that `main.R` has been edited simultaneously on both branches. Everything between `<<<<<<< HEAD` and `=======` is what was written in the current branch (i.e. task3) and everything between `=======` and `>>>>>>> task1` is from the branch that we're trying to merge *into* the current branch. Looking at the code, we can see that it needs the intervention of the person(s) writing the code to decide how the two pieces of code should be combined. In this case, there's a duplicated line that we can get rid of and then some lines that we need to make sure are in the right order. So now replace the lines between (and including) `<<<<<<< HEAD` and `>>>>>>> task1` with the following:

```
library(dplyr)
library(ggplot2)
library(tidyr)

source('R/plots.R')
```

```
source('R/utils.R')

dfKS4tidied <- tidy_subject_timeseries(dfKS4)
plot_ACrange_tidy(dfKS4tidied)
```

We've made a change to a file, so to fully resolve the conflict (and complete the merge), we'll need to perform and `add` and `commit`. Do that whichever way you prefer and at that point the task1 branch will be fully merged into the `task3` branch.

Now we'll look at how a merge works via a pull request.

Pull requests #1

Whilst the basic merges above work fine for pulling in some simple changes, using `git merge` via the terminal lacks any collaborative functionality like discussing and reviewing changes. This is where pull requests come in to play. Pull requests are a part of both GitHub and Dev Ops and provide similar functionality between those two platforms. Here we're using Azure Dev Ops, but a lot of this will be transferrable to using GitHub.

Go to your repo in Azure Dev Ops and select Branches from the left hand navigation panel under Repos. Select the branch for task3 (`grN_task3`). You should see a panel near the top of the branch page telling you that "You updated grN_task3 Just now". At the right hand side of this panel, there should be an option to create a pull request, click this!

Once the create pull request page has loaded you should see a few text boxes to full in and a handful of options to make choices on. The default for a new pull request is to merge into main, but here we want to merge into your group's branch, so click on `main` near the top and select `workshop_group_N`.

You should see three tabs: Overview, Files and Commits. Try clicking onto the Files and Commits tabs and you'll be given the details of what's being included in the planned merge. You should see all the file changes and commits made as part of task3 and task1 (which was merged into task3 above).

Now back on Overview, give the pull request a descriptive title (e.g. "Tidied data frame and created ggplot") and a quick description in the relevant boxes. Then assign your teammates as reviewers and then click create pull request.

You and your team mates will now have a pull request available under the pull requests panel where they can review the changes, add comments and provide approval. Get your

teammates to run through a quick review and approve the pull request. You'll then be able to complete the merge by clicking the blue **Complete** button at the top of the page.

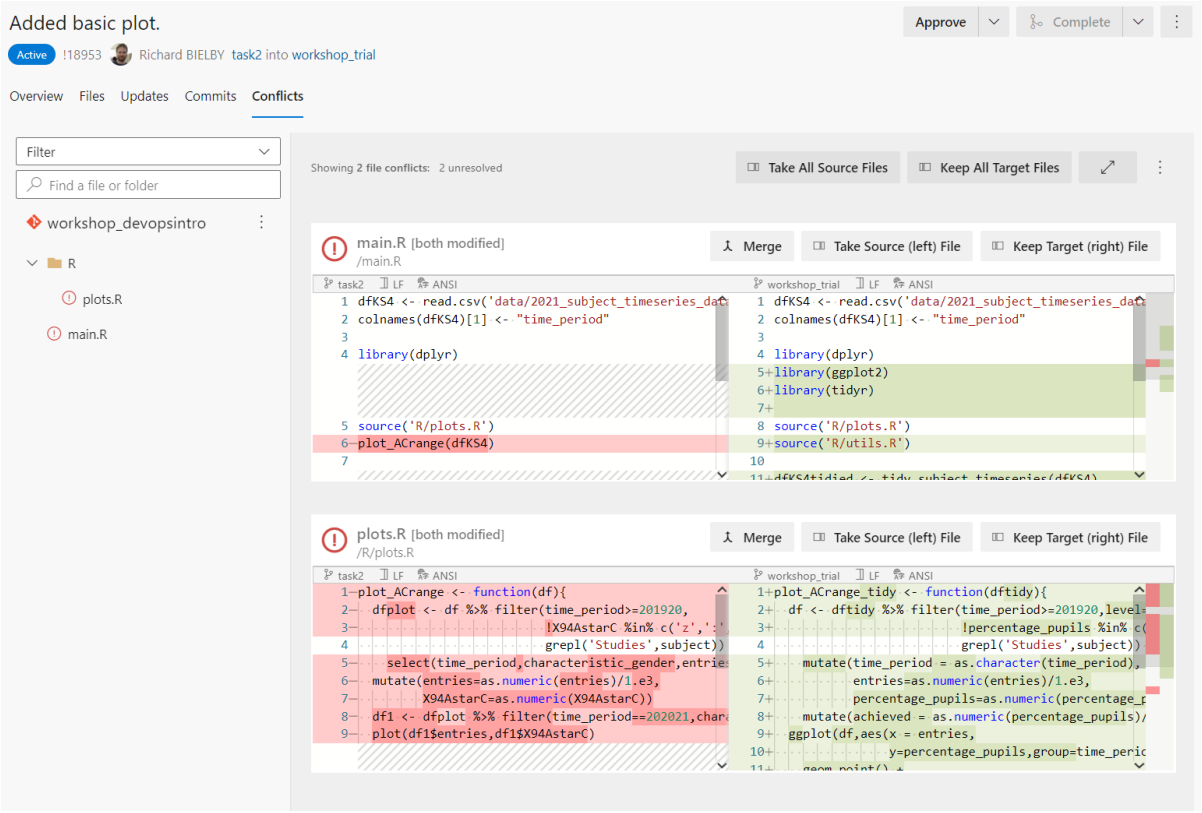
Now head over to Dev Ops Boards and drag tasks 1 and 2 across to Closed to mark them as finished.

Pull requests #2 (and another merge conflict)

We've got one final branch to merge in to complete the work: grN_task2. Whoever worked on task 2 should now go to Boards in Dev Ops and find their task. Open it up and under **Development**, select **Create a Pull Request**. Again, direct the merge into `workshop_group_N` instead of `main` and give the PR a title, description and reviewers, then click **Create**.

Once you've created the pull request, you should find that this time there's a merge conflict. Now instead of editing the conflicting file(s) in R-Studio, you'll be able to resolve the conflict on Dev Ops. Click on the conflicts tab and review the conflict. It should look something like the following:

Figure 5: Staging files in the RStudio git panel.



You've got three options for resolving the conflict: **Merge**, **Take Source (left) file** and **Take Target (right) file**. For a simple conflict where just one or the other version is appropriate then you can click the corresponding of the latter two options. Here we have something a little more complicated, so we want to go in and edit and re-arrange the code ourselves. Click **Merge** and you'll get a new screen showing the two versions side by side with an editor panel below.

For the `main.R` file, change the conflicting lines in the editor to be the following and then click **Submit merge**.

```
library(dplyr)
library(ggplot2)
library(tidyr)

source('R/plots.R')
source('R/utils.R')

plot_ACrange(dfKS4)

dfKS4tidied <- tidy_subject_timeseries(dfKS4)
plot_ACrange_tidy(dfKS4tidied)
```

And for the `plots.R` file, simply remove the **auto-generated** lines in the editor (you might also get asked to add a line ending, in which case choose *LF*) and again click **Submit merge**.

Back on the Overview page, it should now say *No merge conflicts* and the **Complete** button should be available to click. Now the PR is ready for your collaborators to review and approve and then you can complete the PR and merge into your group's workshop branch.

Once you've completed the PR, head back to the team board on Dev Ops and open up the task 2. You'll now see that the PR is listed under the Devlopement section on the right as completed. To mark the task as finished, close the task dialogue box and drag the task from Active to Closed.

Notes on reviewing a pull request

There are some basic steps to go through if you're asked to review a pull request. The key elements are:

1. Review any automated checks or QA scripts;
2. Clone the repository, switch to the relevant branch and run the code;
3. Look through and comment on the changes to the repository using the **Files changes** panel in the PR.

In this case, we don't have any automated checks set up properly, so we'll focus on points 2 and 3.

First of all try switching to the *featTimeSeriesChart* branch if you're not already in it and run the Shiny app - this can be done by opening the global.R script in RStudio and clicking Run App in the top right hand corner of the viewer pane. Assuming the dashboard runs, then try cycling through the different panels of the dashboard looking for any problems, errors or just things that could be improved.

There should be plenty of issues to find as we've kept the actual dashboard coding brief to focus on using git. As you find them, enter them in to the GitHub pull request, either under **Review changes** on the Files changed panel or as comments in the **Conversation** panel.

In reality, once you've got those reviews collated, you'd go through and make changes to the code accordingly. This provides the checks and balances and a structure for code QA necessary when developing reproducible analyticle pipelines or data dashboards.

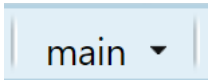
Assuming we've dealt with the outcomes of those reviews appropriately, the next step is to complete the Pull request by clicking the **Merge pull request** button. This then completes the merge in to *main* in this case. Whilst the basic mechanics of what's happening with the branches is the same here as with just running `git merge`, the Pull request provides that extra layer of administrative structure to perform proper QA of the code and the resulting product.

Summary

We've looked through a lot of the basics in this section, covering adding/staging, committing, pushing/pulling between remote and local repos, merging and pull requests. These are all the main concepts you need to use git.

We've also tried to cover doing all this through a mixture of RStudio, git BASH and GitHub (and as we've said Azure Dev Ops offers similar functionality to GitHub). Most common processes can be done multiple ways and there's not necessarily a single right method to follow, just whichever makes most sense in your situation.

Just a quick final note on why it's useful to be familiar with git `BASH`. Whilst most of the basic git functionality can be accessed via the RStudio panel or GitHub/Dev Ops, there are some things that are best achieved through BASH. In particular, if you have a file in your repo that you need to remove entirely, this pretty much requires someone to use commands via git BASH.

Process	git BASH	RStudio git panel
Create branch	`git checkout -b branch_name`	
Switch branch	`git checkout branch_name`	
Merge branch	`git merge branch_name`	N/A - use GitHub/Dev Ops

Troubleshooting

renv

If `renv::restore()` causes issues, then one of your team should try `renv::init()` and select option 2 to restart renv. Then do a add/commit/push cycle and get the other team members to do a pull and then try running `renv::restore()` again on their local clones of the repo.

Datafiles commit-hooks/`.gitignore`

To help teams keep on top of avoiding any accidental publishing of unpublished data, we've added in some code around commits that checks through any data files in the repo and checks them against a logfile and the .gitignore file. Any files listed in .gitignore will not be included in commits and therefore won't be sent to the remote repo as part of any push.

merge conflicts

Merge commits happen when two branches have conflicting changes that have been made concurrently. `git` can usually figure out how to prioritise changes based on the commit history, but if changes have happened at the same time to the same bit of code across different branches, then it will need to get your input on how to prioritise the changes.

The easiest way to go through how to deal with merge conflicts is by discussing with an example, so ask us in the workshop if and when you hit a merge conflict.

Briefly though, when there's a merge conflict, git will add some text to the file containing the conflict along the following lines:

```
<<<<<<<<<<< branch_1
code
on
branch
1
```

```
===========
conflicting code on branch 2
>>>>>>>>>>> branch_2
```

Effectively as the user, you need to decide which bit of code is the right bit to keep and then delete anything you don't want to keep as well as the tag-lines that git has added in. So for example, you should be left with something along the lines of:

```
code
on
branch
1
```

Once you've cleared up all merge conflicts in the branch that you're working on, then perform another add/commit cycle and thay should clear out the conflict from the branch that you're working on and you'll be able to continue with the intended merge/PR.

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