UMD DATA605 - Big Data Systems

Git, Data Pipelines

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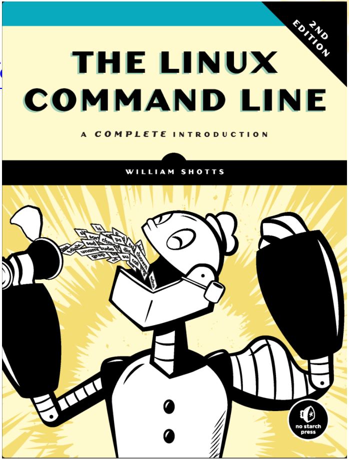
Bash / Linux: Resources

- Command line
  - https://ubuntu.com/tutorials/command-line-f
- E.g., `find`, `xargs`, `chmod`, `chown`, symbolic, and hard links
- How Linux works
  - Processes
  - File ownership and permissions
  - Virtual memory
  - How to administer a Linux box as root
- Mastery
  - https://linuxcommand.org/tlcl.php
  -



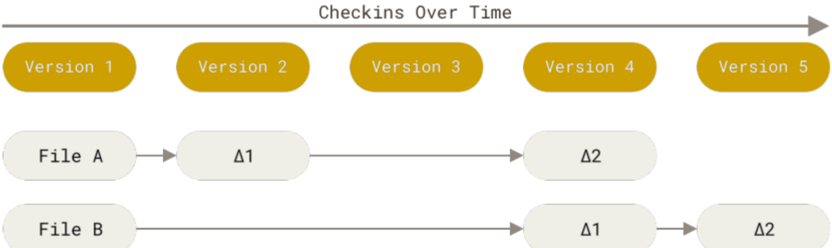
Git Resources

Version Control Systems

- A Version Control System (VCS) is a system that allows to:
  - Record changes to files
  - Recall specific versions later (like a “file time-machine”)
  - Compare changes to files over time
  - Track *who* changed *what* and *when* and *why*
- **Simplest "VCS"**
  - Make a copy of a dir and add `_v1` (bad) or add a timestamp `_20220101` (better)
  - Make a copy of a dir and add `_v1` (bad) or add a timestamp `_20220101` (better)
  - **Cons**: It kind of works for one person, but doesn’t scale
- **Centralized VCS**
  - E.g., Perforce, Subversion
  - A server stores the code, clients connect to it
  - **Cons**: If the server is down, nobody can work
- **Distributed VCS**
  - E.g., Git, Mercurial, Bazaar, Dart
  - Each client has the entire history of the repo locally
  - Each node is both a client and a server
  - **Cons**: complex

VCS: How to Track Data

- Consider a directory with project files inside
- **How do you track changes to the data?**
- **Delta-based VCS**
  - E.g., Subversion
  - Store the data in terms of patches (changes of files over time)
  - Can reconstruct the state of the repo by applying the patches
- **Stream of snapshots VCS**
  - E.g., Git
  - Store data in terms of snapshots of a filesystem
  - Take a "picture" of what files look like
  - Store reference (hash) to the snapshots
  - Save link to previous identical files

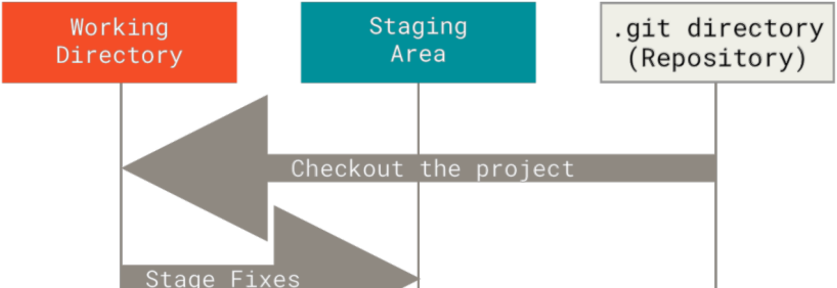


Git

- Almost everything is local for Git
  - The history is stored locally in each node
  - Diff-ing is done locally
    - For centralized VCS you need to access the server
  - You can commit to your local copy
    - Upload changes when there is network connection
- Almost everything is undoable in Git
  - No data corruption
    - Everything is checksummed
  - Nothing can be lost
  - Disclaimer:
    - As long as you commit (at least locally) or stash
    - As long as you don't precipitate in "git hell"
    - You need to know how to do it
- Git is a mini key-value store with a VCS built on top
  - This is actually exactly true
  - Two layers:
    - "porcelain": key-value store for a file-system
    - "plumbing": VCS layer

States of a File in Git

There are 3 main sections of a Git project: - **Working tree** (aka checkout) - Version of the code placed on the filesystem for the user to use and modify - **Staging area** (aka cache, index) - A file in `.git` that stores information about the next commit - **Git directory** (aka .git) - Store metadata and objects (like a DB) - It is the repo itself with all history - When you clone, you get the `.git` of the project Each file can be in 4 states from Git point-of-view - **Untracked**: files that are not under Git version control - **Modified**: you have changed the file, but not committed to DB yet - **Staged**: you have marked a modified file to go into your next commit snapshot - **Committed**: data is safely stored in your local DB



Git Tutorial

- Git tutorial on class repo
  - Read me
- How to use a tutorial
  - Type the commands from the tutorial one-by-one
    - Do not copy paste
  - Look at the results
    - Understand what each line means
  - Play with things
    - "What happens if I do this?"
    - "Does the result match my mental model?"
  - Learn command line before switching to the GUI
    - GUIs hide details and you become dependent on it
- Use one or more tutorials on-line
  - Ideally go through the Git book and the examples
- Build your own cheat sheet
  - Reusing other people cheat sheet works only if you already know
- Strive to achieve mastery of the basic tools of the trade
  - Bash, Git, editor
  - Python
  - Pandas
  -

Git: Daily Use

- Check out a project (git clone) or start from scratch (git init)
  - Only once per Git project client
- **Daily routine**
  - Modify files in working tree (vi . . .)
  - Add files (git add . . .)
  - Stage changes for the next commit (git add -u . . .)
  - Commit changes to .git (git commit)
- **Use a branch to group commits together**
  - Isolate your code from changes in master
  - Merge master into your branch
  - Isolate master from your changes
  - Pull Request (aka PR) to get the code reviewed
  - Merge PR into upstream

Git Remote

- Remote repos are versions of the project hosted on Internet/remote file system
  - To collaborate you need to manage remote repos
  - Push / pull changes
- You can have multiple forks of the same repo with different policies
  - E.g., read-only, read-write
- `git remote -v`: show what are the remotes
- `git fetch`: pull from the remote repo all the data (e.g., branches, commits) that you don't have locally
- `git pull`: short hand from `git fetch origin` + `git merge master --rebase`
- `git push <REMOTE> <BRANCH>`: push local data to a remote
  - E.g., `git push origin master`
- If somebody pushed to the remote, you can't push your changes right away, but you need to:
  - Fetch the changes
  - Merge changes to the branch in your client
  - Resolve conflicts, if needed
  - (Test project sanity, e.g., by running unit tests)
  - Push changes to the remote

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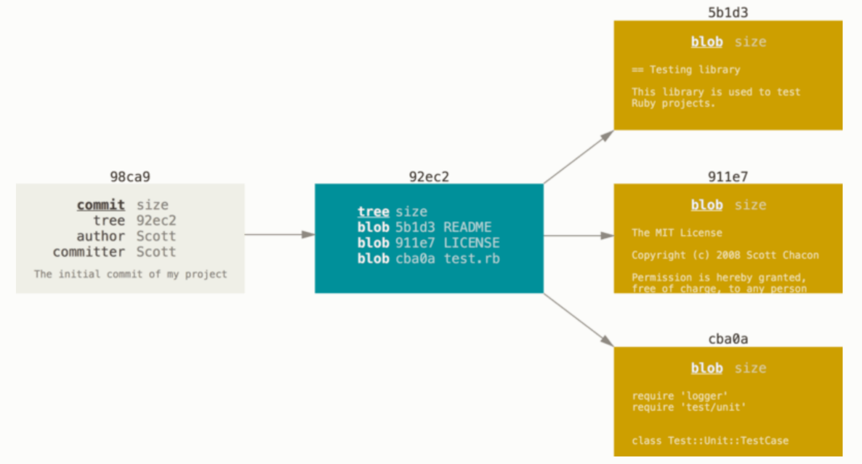
Git Tagging

- Git allows to mark specific points in history with a tag
  - E.g., release points
- You can check out a tag
- You get in detached `HEAD` state
  - If you commit your change won't be added to the tag or to the branch
  - The commit will be "unreachable", i.e., reachable only by the commit hash

Git Internals



- **You can understand Git only if you understand the data model**
  - Git is a key-value store with a VCS user interface on top of it
  - Key = hash of a file
  - Value = content of a file

Git Branching

- **Branching**
    - = diverging from the main line of development
- **Why branch?**
    - Work without messing the rest of the code
    - Work without being affected by changes in the main branch
    - Merge the code downstream to pick up the changes
    - Once you are done working in your branch, merge code upstream
- **Git branching is lightweight**
    - It's instantaneous
    - A branch is just a pointer to a commit
    - Git doesn't store data as difference of files, but as a series of snapshot
- **Git workflows branch and merge often**
    - Even multiple times a day
    - This is surprising for people used to distributed VCS
        - E.g., you would start branching before going for lunch
    - Branches are cheap in Git
        - Use them all the times to isolate your work and organize it

Git Branching

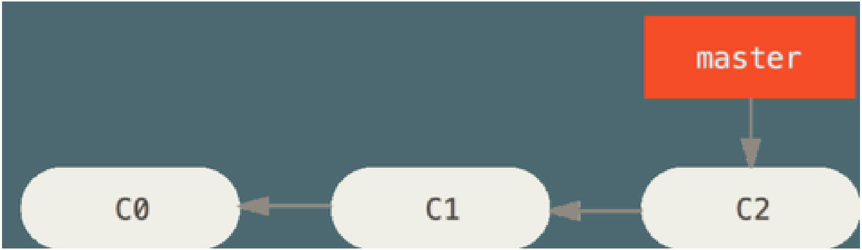
- master (or **main**) is just a normal branch
  - master is a pointer to the last commit
  - As you commit the pointer moves forward
- `HEAD`
  - Pointer to the local branch you are on
  - E.g., master, testing
  - `git checkout <BRANCH>` moves you across branches
- `git branch testing`
  - Create a new pointer `testing`
  - Point to the commit you are on
  - Pointer can be moved around
- Divergent history
  - When work progresses in two branches that are "split"

Git Checkout

- `git checkout` switches branch
  - Move `HEAD` pointer to the new branch
  - Change the files in the working dir to match the state corresponding to the branch pointer
- E.g., there are two branches master and testing
  - You are on master
  - `git checkout testing`
  - The pointer moves, the working dir is changed (not really in this case)
  - Then you can keep working by committing on **testing**
  - The pointer to **testing** moves forward (no divergent history)

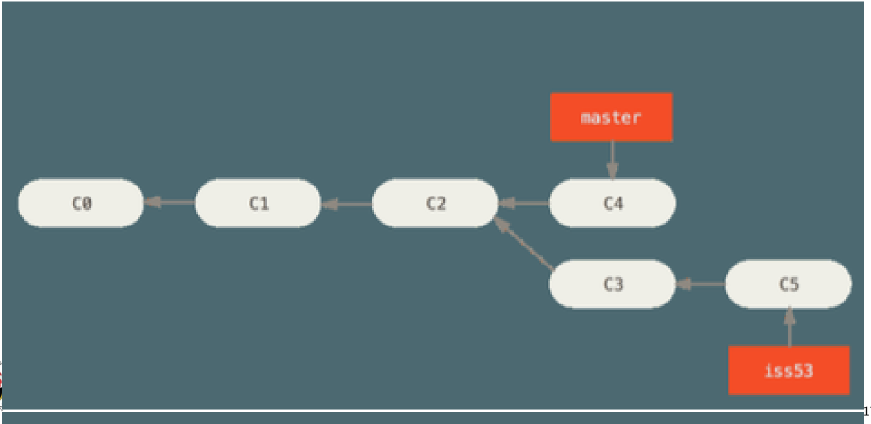
Git Branching and Merging

-Tutorials: Work on main, Hot fix Start from a project with some commits Branch to work on a new feature “Issue 53” > `git checkout -b iss53` **work ... work ... work** > `git commit` Need a hotfix to master > `git checkout master` > `git checkout -b hotfix` **fix ... fix ... fix** > `git commit -am "Hot fix"` > `git checkout master` > `git merge hotfix` **Fast forward** Now there is a divergent history between `master` and `iss53`



Git Branching and Merging

`> git checkout iss53` **work … work … work** The branch keeps diverging At some point you are done with **iss53** You want to merge your work back to **master** Go to the target branch `> git checkout master` `> git merge iss53` Git can't fast forward Git creates a new snapshot with the 3-way "merge commit" (commit with more than one parent) Delete the branch `> git branch -d iss53`



Fast Forward Merge

- **Fast forward merge** = merge a commit X with a commit Y that can be reached by following the history of commit X**
- There is not divergent history to merge
- Git simply moves the branch pointer forward from X to Y
- **Mental model**: a branch is just a pointer that says where the tip of the branch is**
- E.g., C4' is reachable from C3 > `git checkout master` > `git merge experiment`
- Git moves the pointer of master to C4'

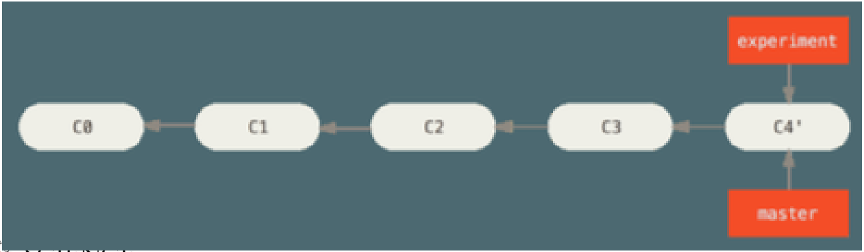


Figure 1: alt_text

Merging Conflicts

- Tutorial:
  - Merging conflicts
- Sometimes Git can't merge, e.g.,
  - The same file has been modified by both branches
  - One file was modified by one branch and deleted by another
- Git:
  - Does not create a merge commit
  - Pauses to let you resolve the conflict
  - Adds conflict resolution markers
- User merges manually
  - Edit the files `git mergetool`
  - `git add` to mark as resolved**
  - `git commit`
  - Use PyCharm

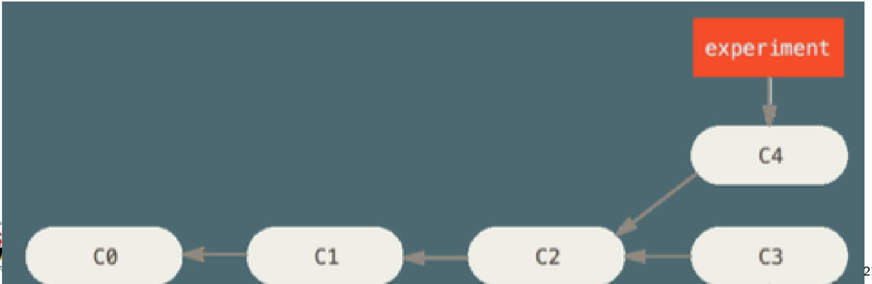
```
<<<<<<< HEAD:index.html
<div id="footer">contact : email.support@github.com</div>
=======
<div id="footer">
 please contact us at support@github.com
```

Git Rebasing

- In Git there are two ways of merging divergent history
  - E.g., **master** and **experiment** have a common ancestor C2
- **Merge**
  - Go to the target branch
  - `> git checkout master`
  - `> git merge experiment`
  - Create a new snapshot C5 and commit
- **Rebase**
  - Go to the branch to rebase
  - `> git checkout experiment`
  - `> git rebase master`
  - Rebase algo:
    - Get all the changes committed in the branch (C4) where we are on (experiment) since the common ancestor (C2)
    - Sync to the branch that we are rebasing onto (master at C3)
    - Apply the changes C4'
    - Only the branch where we are is affected
  - Finally fast forward master

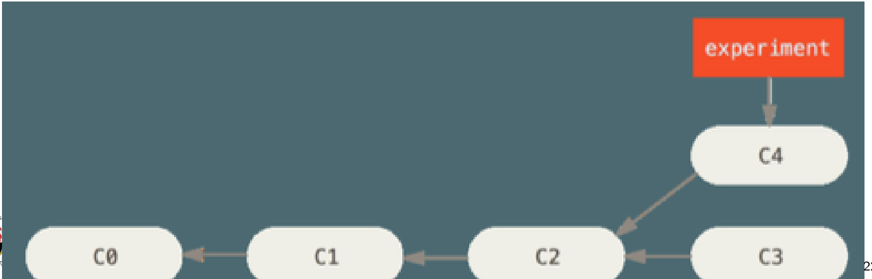
Uses of Rebase

- **Rebasing makes for a cleaner history**
  - The history looks like all the work happened in series
  - Although in reality it happened in parallel to the development in master
- **Rebasing to contribute to a project**
  - Developer
    - You are contributing to a project that you don't maintain
    - You work on your branch
    - When you are ready to integrate your work, rebase your work onto **origin/master**
  - The maintainer
    - Does not have to do any integration work
    - Does just a fast forward or a clean apply (no conflicts)



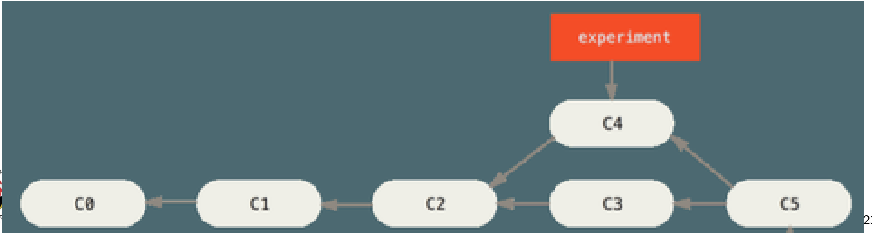
Golden Rule of Rebasing

- **Remember**: rebasing means abandoning existing commits and creating new ones that are similar but different
- **Problem**
  - You push your commits to a remote somewhere
  - Others pull your commits down and base their work on them
  - You rewrite those commits with `git rebase`
  - You push them again with **git push –force
  - Your collaborators have to re-merge their work
- **Solution Strict version**: "Do not **ever** rebase commits that exist outside your repository" **Loose version**: "It's ok to rebase your branch even if you pushed to a server, as long as you are the only one to use it"



Rebase vs Merge: Philosophical Considerations

- Rebase-vs-merge depend on the answer to the question:
- **What does the commit history of a repo mean?**
- **a) History is the record of what actually happened**
- *"History should not be tampered with!"**
- **Q: What if there is a series of messy merge commits?**
- **A: This is how it happened. The repo should preserve this**
- Use `git merge`
- **b) History represents how a project should have been made**
- *"You would not publish a book as a sequence of drafts and correction, but rather the final version"*
- *You should tell the history in the way that is best for future readers*
- Use `git rebase` and filter-branch**



Rebase vs Merge: Philosophical Considerations

- Many man-centuries have been wasted discussing rebase-vs-merge at the watercooler
  - Total waste of time! Tell people to get back to work!
- When you contribute to a project often people decide for you based on their preference
- **Best of the merge-vs-rebase approaches**
- Rebase changes you've made in your local repo
  - Even if you have pushed but you know the branch is yours
  - Use `git pull --rebase` to clean up the history of your work
  - If the branch is shared with others then you need to definitively `git merge`
- Only `git merge` to master to preserve the history of how something was built
- **Personally**
- I like squash-and-merge branches to master
  - My commits are just my checkpoints
  - Rarely they are "complete"

Remote Branches

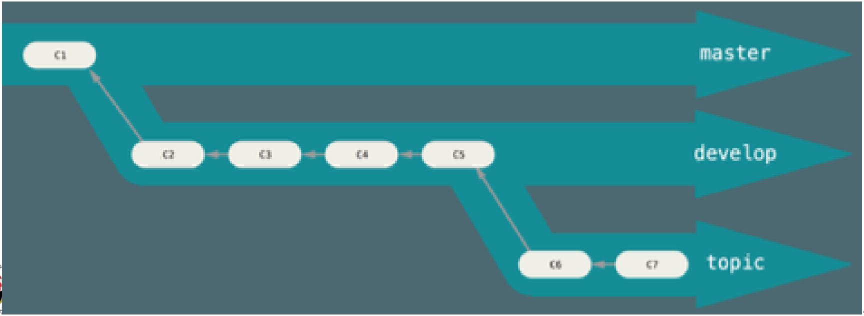
- Remote branches are pointers to branches in remote repos

```
git remote -v
origin  git@github.com:gpsaggese/umd_data605.git (fetch)
origin  git@github.com:gpsaggese/umd_data605.git (push)
```

- **Tracking branches**
  - Local references representing the state of the remote repo
  - E.g., **master** tracks **origin/master**
  - You can't change the remote branch (e.g., **origin/master**)
  - You can change tracking branch (e.g., **master**)
  - Git updates tracking branches when you do `git fetch origin` (or `git pull`)
- To share code in a local branch you need to push it to a remote
  - `> git push origin serverfix`
- To work on it
  - `> git checkout -b serverfix origin/serverfix`

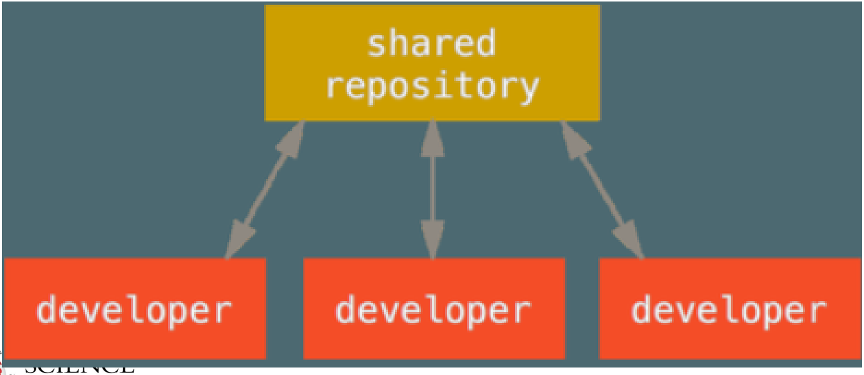
Git Workflows

Git workflows - = ways of working and collaborating using Git **Long-running branches** - Branches at different level of stabilities, that are always open - **master** is always ready to be released - **develop** branch to develop in - *topic* / *feature* branches - When branches are "stable enough" they are merged up **Topic branches** - Short-lived branches for a single feature - E.g., **hotfix**, **wip-XYZ** - Easy to review - Silo-ed from the rest - This is typical of Git since other VCS support for branches is not good enough - E.g., - You start **iss91**, then you cancel some stuff, and go to **iss91v2** - Somebody starts **dumbidea** branch and merge to **master** (!) - **You squash-and-merge your** iss91v2**



Centralized Workflow

Centralized workflow in centralized VCS - Developers: - Check out the code from the central repo on their computer - Modify the code locally - Push it back to the central hub (assuming no conflicts with latest copy, otherwise they need to merge) **Centralized workflow in Git** - Developers: - Have push (i.e., write) access to the central repo - Need to fetch and then merge - Cannot push code that will overwrite each other code (only fast-forward changes)



Forking Workflows

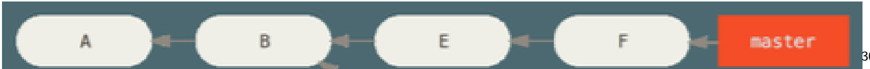
- Typically devs don't have permissions to update directly branches on a project
  - Read-write permissions for core contributors
  - Read-only for anybody else
- **Solution**
  - "Forking" a repo
  - External contributors
    - Clone the repo and create a branch with the work
    - Create a writable fork of the project
    - Push branches to fork
    - Prepare a PR with their work
  - Project maintainer
    - Reviews PRs
    - Accepts PRs
    - Integrates PRs
  - In practice it's the project maintainer that pulls the code when it's ready, instead of external contributors pushing the code
- **Aka "GitHub workflow"**
  - "Innovation" was forking (Fork me on GitHub!)
  - GitHub acquired by Microsoft for 7.5b USD

Integration-Manager Workflow

- This is the classical model for open-source development
  - E.g., Linux, GitHub (forking) workflow
- **1. One repo is the "official" project**
  - Only the project maintainer pushes to the public repo
  - E.g., **sorrentum/sorrentum**
- **2. Each contributor**
  - Has read access to everyone else's public repo
  - Forks the project into a private copy
    - Write access to their own public repo
    - E.g., **gpsaggese/sorrentum**
  - Makes changes
  - Pushes changes to his own public copy
  - Sends email to maintainer asking to pull changes (pull request)
- **3. The maintainer**
  - Adds contributor repo as a remote
  - Merges the changes into a local branch
  - Tests changes locally
  - Pushes branch to the official repo

Git log

- `git log` reports info about commits**
- **refs** are references to:
  - `HEAD` (commit you are working on, next commit)
  - `origin/master` (remote branch)
  - experiment (local branch)
  - d921970 (commit)
- after a reference resolves to the parent of that commit
- `HEAD` = commit before `HEAD`, i.e., last commit
- 2 means
- A merge commit has multiple parents
- **Double-dot notation**
  - 1..2 = commits that are reachable from 2 but not from 1 (difference)**
  - `git log master..experiment $\to$ D,C`
  - `git log experiment..master $\to$ F,E`
- **Triple-dot notation**
  - **1...2** = commits that are reachable from either branch but not from both (union excluding intersection)**
  - `git log master...experiment $\to$ F,E,D,C`



Advanced Git

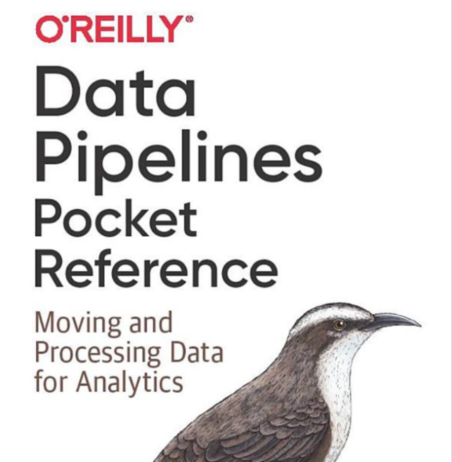
- stashing
  - Copy state of your working dir (e.g., modified and staged files), save it in a stack, to apply later
- cherry-picking
  - Rebase for a single commit
- rerere
  - = "Reuse Recorded Resolution"
  - Git caches how to solve certain conflicts
- tagging
  - Give a name to a specific commit (e.g., v1.3)
- submodules / subtrees
  - Project including other Git projects
- bisect
  - Sometimes a bug shows up at top of tree
  - You don't know at which revision it started manifesting
  - You have a script that returns 0 if the project is good and non-0 if the project is bad
  - `git bisect` can find the revision at which the script goes from good to bad**
- filter-branch
  - Rewrite repo history in some script-able way

GitHub

- GitHub acquired by MSFT for 7.5b
- **GitHub: largest host for Git repos**
  - Git hosting (100m+ open source projects)
  - PRs, forks
  - Issue tracking
  - Code review
  - Collaboration
  - Wiki
  - Actions (CI / CD)
- **"Forking a project"**
  - In open-source communities
    - It had a negative connotation
    - Take a project, modify it, and make it a competing project
  - In GitHub parlance
    - Make a copy of a project so that you can contribute to it even if you don't have push / write access

Data Pipelines - Resources

- Concepts in the slides
- Class project
- Mastery
  - Data Pipelines Pocket Reference: Moving and Processing Data for Analytics

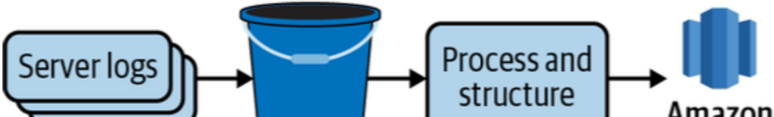


Data as a Product

- **Many services today "sell" data**
  - Services are typically powered by data and machine learning
  - Data products, e.g.,
    - Personalized search engine (Google)
    - Sentiment analysis on user-generated data (Facebook)
    - A recommendation engine + e-commerce (Amazon)
    - Streaming data (Netflix, Spotify)
- **Several steps are required to generate data products**
  - Data ingestion
  - Data pre-processing
    - Cleaning, tokenization, feature computation
  - Model training
  - Model deployment
    - MLOps
  - Model monitoring
    - Is model working?
    - Is model getting slower?
    - Are model performance getting worse?
  - Collect feedback from deployment
    - E.g., recommendations vs what users bought
    - Ingest data from production for future versions of the model

Data Pipelines

- "Data is the new oil"
  - ... but oil needs to be refined
- **Data pipelines**
  - Processes that move and transform data
  - **Goal**: derive new value from data through analytics, reporting, machine learning**
- Data needs to be:
  - Collected
  - Pre-processed / cleaned
  - Validated
  - Processed
  - Combined
- **Data ingestion**
  - Simplest data pipeline
  - Extract data (e.g., from REST API)
  - Load data into DB (e.g., SQL table)



Roles in Building Data Pipelines

- **Data engineers**
  - Build and maintain data pipelines
  - Tools:
    - Python / Java / Go / No-code
    - SQL / NoSQL stores
    - Hadoop / MapReduce / Spark
    - Cloud computing
- **Data scientists**
  - Build predictive models
  - Tools:
    - Python / R / Julia
    - Hadoop / MapReduce / Spark
    - Cloud computing
- **Data analysts**
  - E.g., marketing, MBAs, sales, ...
  - Build metrics and dashboards
  - Tools:
    - Excel spreadsheets
    - GUI tools (e.g., Tableaux)
    - Desktop
- **Recurring practical problems**
  - Who is responsible for the data?
  - Issues with scaling

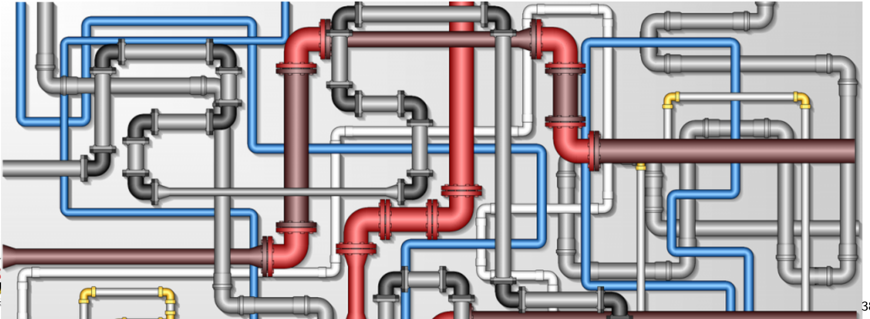
SCIENCE ACADEMY

Data Ingestion

- **Data ingestion**
  - = extract data from one source and load it into another store
- **Data sources / sinks**
  - DBs
    - E.g., Postgres, MongoDB
  - REST API
    - Abstraction layer on top of DBs
  - Network file system / cloud
    - E.g., CSV files, Parquet files
  - Data warehouses
  - Data lakes
- **Source ownership**
  - An organization can use 10-1000s of data sources
  - Internal
    - E.g., DB storing shopping carts for a e-commerce site
  - 3rd-parties
    - E.g., Google analytics tracking website usage

Data Pipeline Paradigms

- There are several styles of building data pipelines
- Multiple phases
  - Extract
  - Load
  - Transform
- Phases arranged in different ways depending on philosophy about data / roles
  - ETL
  - ELT
  - EtLT



ETL Paradigm: Phases

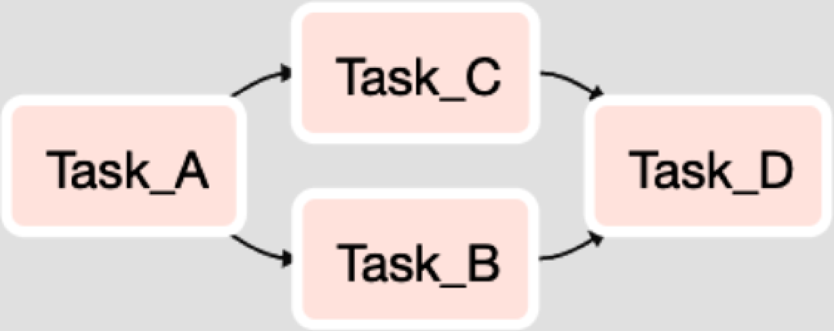
- **Extract**
  - Gather data from various data sources, e.g.,
    - Internal / external data warehouse
    - REST API
    - Data downloading from API
    - Web scraping
- **Transform**
  - Raw data is combined and formatted to become useful for analysis step
- **Load**
  - Move data into the final destination, e.g.,
    - Data warehouse
    - Data lake
- **Data ingestion pipeline = E + L**
  - Move data from one point to another
  - Format the data
  - Make a copy
  - Have different tools to operate on the data

ETL Paradigm: Example

- **Extract**
  - Buy-vs-build data ingestion tools
    - Vendor lock-in
- **Transform**
  - Data conversion (e.g., parsing timestamp)
  - Create new columns from multiple source columns
    - E.g., year, month, day -> yyyy/mm/dd
  - Aggregate / filter through business logic
    - Try not to filter, better to mark
  - Anonymize data
- **Load**
  - Organize data in a format optimized for data analysis
    - E.g., load data in relational DB
  - Finally data modeling

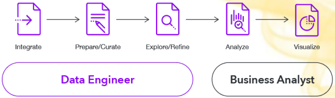
Workflow Orchestration

- Companies have many (10-1000s) data pipelines
- Orchestration tools, e.g.,
  - Apache Airflow (from AirBnB)
  - Luigi (from Spotify)
  - AWS Glue
  - Kubeflow
- Schedule and manage flow of tasks according to their dependencies
  - Pipeline and jobs are represented through DAGs
- Monitor, retry, and send alarms



ELT paradigm

- ETL has been the standard approach for long time
  - Extract → Transform → Load
  - **Cons**
    - Need to understand the data at ingestion time
    - Need to know how the data will be used
- **Today** ELT is becoming the pattern of choice**
  - Extract → Load → Transform
  - **Pro**:
    - No need to know how the data will be used
    - Separate data engineers and data scientists / analysts
    - Data engineers focus on data ingestion (E + L)
    - Data scientists focus on transform (T)
- **ETL → ELT enabled by new technologies**
  - Large storage to save all the raw data (cloud computing)
  - Distributed data storage and querying (e.g., HDFS)
  - Columnar DBs



SCIENCE ACADEMY

Row-based vs Columnar DBs

- **Row-based DBs**
  - E.g., MySQL, Postgres
  - Optimized for reading / writing rows
  - Read / write small amounts of data frequently
- **Columnar DBs**
  - E.g., Amazon Redshift, Snowflake
  - Read / write large amounts of data infrequently
  - Analytics requires a few columns
  - Better data compression

OrderId	CustomerId	ShippingCountry	OrderTotal
1	1258	US	55.25
2	5698	AUS	125.36
3	2265	US	776.95
4	8954	CA	32.16

Block 1	1, 1258, US, 55.25
Block 2	2, 5698, AUS, 125.36
Block 3	3, 2265, US, 776.95
Block 4	4, 8954, CA, 32.16

SCIENCE ACADEMY

EtLT

- **ETL**
  - Extract → Transform → Load
- **ELT**
  - Extract → Load → Transform
  - Transformation / data modeling ("T") according to business logic
- **EtLT**
  - Sometimes transformations with limited scope ("t") are needed
    - De-duplicate records
    - Parse URLs into individual components
    - Obfuscate sensitive data (for legal or security reasons)
  - Then implement rest of "LT" pipeline

Structure in Data (or Lack Thereof)

- **Structured data**: there is a schema
  - Relational DB
  - CSV
  - DataFrame
  - Parquet
- **Semi-structured**: subsets of data have different schema
  - Logs
  - HTML pages
  - XML
  - Nested JSON
  - NoSQL data
- **Unstructured**: no schema**
  - Text
  - Pictures
  - Movies
  - Blobs of data

OLAP vs OLTP Workloads

- There are two classes of data workloads
- **OLTP**
  - **O**n-**L**ine **T**ransactional **P**rocessing
  - Execute large numbers of transactions by a large number of processes in real-time
  - **Lots of concurrent small read / write transactions**
  - E.g., online banking, e-commerce, travel reservations
- **OLAP**
  - **O**n-**L**ine **A**nalytical **P**rocessing
  - Perform multi-dimensional analysis on large volumes of data
  - **Few large read or write transactions**
  - E.g., data mining, business intelligence

Challenges with Data Pipelines

- High-volume vs low-volume
  - Lots of small reads / writes
  - A few large reads / writes
- Batch vs streaming
  - Real-time constraints
- API rate limits / throttling
- Connection time-outs
- Slow downloads
- Incremental mode vs catch-up

SCIENCE ACADEMY

Data Warehouse vs Data Lake

- **Data warehouse**
  - = DB storing data from different systems in a structured way
  - Corresponds to ETL data pipeline style
  - E.g., a large Postgres instance with many DBs and tables
  - E.g.,
    - AWS Athena, RDS
    - Google BigQuery
- **Data lake**
  - = data stored in a semi-structured or without structure
  - Corresponds to ELT data pipeline style
  - E.g., an AWS S3 bucket storing blog posts, flat files, JSON objects, data605/lectures_source/images

Data Lake: Pros and Cons

- Data lake = stores data in a semi-structured or without structure
- **Pros**
  - Storing data in cloud storage is cheaper
  - Making changes to types or properties is easier since it's unstructured or semi-structured (with no predefined schema)
    - E.g., JSON documents
  - Data scientists
    - Don't know initially how to access and use the data
    - Want to explore the raw data
- **Cons**
  - It is not optimized for querying like a structured data warehouse
    - There are tools that allow to query data in a data lake similar to SQL
    - E.g., AWS Athena, Redshift Spectrum

Advantages of Cloud Computing

- **Ease of building and deploying:**
  - Data pipelines
  - Data warehouses
  - Data lakes
- **Managed services**
  - No need for admin and deploy
  - Highly scalable DBs
    - E.g., Amazon Redshift, Google BigQuery, Snowflake
- **Rent-vs-buy**
  - Easy to scale up and out
  - Easy to upgrade
  - Better cash-flow
- **Cost of storage and compute is continuously dropping**
  - Economies of scale
- **Cons**
  - The flexibility has a cost (2x-3x more expensive than owning)
  - Vendor lock-in