**Problem Statement**: Explore which federal government agencies have the highest web traffic and which have low traffic and how this varies over time. The federal government provides a vast array of services and information to the American people through its websites. Websites that have little traffic may be poorly designed or not well-publicized. When websites have very high traffic, this may imply that the government must be prepared with resources to meet the high demand for both web traffic and downstream service delivery. In this project, I build a data pipeline, ingesting data in batches from an API weekly, transforming the data with Spark, storing the data in a mySQL database, and visualizing the output with python’s altair package. I orchestrate the workflow with Apache Airflow.

**High Level Overview of Steps**

1. Install required software
2. Use python to extract historical website visits data from the analyicts.usa.gov API (Jan 1, 2020 through May 1, 2023) and store the raw data in a mySQL database.
3. Setup directed acyclic graph in Apache Airflow to do the following steps **once a week:**
   1. Task 1: Extract the latest website visits data
   2. Task 2: Transform and store the data so it is ready for analysis.
   3. Task 3: Load transformed data into mysql into python. Visualize using the python altair package.

**Big Dataset Source**: [analytics.usa.gov API](https://open.gsa.gov/api/dap/)

**Hardware**: MacOS Monterey Version 12, M1 chip, 16GB

**Software:** Python 3.9, Spark 3.3.1, Apache Airflow 2.6.0

**Benefits**: Airflow has a user-friendly visual display of the pipeline.

**Challenges**: I encountered a few hiccups as I was new to the airflow technology (1) airflow uses the UTC timezone for scheduling jobs (2) if you need to update the configuration file, afterwards, be sure to reset the airflow database, webserver, and scheduler. (3) Your scheduler’s first run is sensitive to the start\_date setting. For example, if you want to run a weekly job that starts today, be sure your start date is more than a week prior to today.

**YouTube URL:** [Short Video](https://youtu.be/AYaaRbIt7I4) | [Long Video](https://youtu.be/CKeJR5OuxSQ). **Git Repo** [Link](https://github.com/jhsmith22/e63finalproject.git).

**DATASET SIZE** (Jan 1, 2019 – May 7, 2023): 3,510,428 rows

**MOST VISITED AGENCIES IN 2023:**

1. Department of Health and Human Services
2. Postal Service
3. Commerce
4. Treasury

**LEAST VISITED AGENCIES IN 2023:**

1. Nuclear Regulatory Commission
2. U.S. International Development
3. National Science Foundation
4. Housing and Urban Development

**NEXT STEPS:**

* Additional data from API: device use (mobile, desktop)
* Analyze individual website domain trends
* Integrate weekly/monthly economic data into the pipeline
* Bring in weekly twitter data for each agency to highlight topics of conversation, key influencers
* Serve on website

# Description of Software tools

Apache Airflow is what is considered a data pipeline orchestrator. It allows you to schedule a series of data pipeline tasks in a particular order to occur at a particular time. For example, you can schedule your data ingestion to happen every day at a certain time, and then sequentially run your other data pipeline steps, such as cleaning, transformation, and visualization. A barebones version of this is the bash Crontab utility. Airflow allows you to schedule a more complex set of tasks. Airflow uses what is called a Directed Acyclic Graph or a DAG to schedule task in a sequential order. You run airflow by starting up both (1) the web server and (2) the scheduler. The metadata for apache airflow is stored in a sqlite database.

I also use python, pyspark, and mysql software, which we cover in-depth in class. The infographic below describes the steps in my data pipeline. I use the **Airflow** as an orchestrator to ingest data in batches once a week. The exhibit below highlights my Extract-Load-Transformation ETL data pipeline that is initialized with Airflow . I use pySpark to initially hold the raw data I pull down from the API. I write the data from pySpark to a mySQL database. I then load the raw data back into pySpark to transform it so it is ready for analysis, aggregating the raw data into monthly visit counts for each agency. Finally, I load the much smaller, aggregated dataset into python and visualize it with the altair package.

**Exhibit 1: Extract-Load-Transform (ELT) Data Pipeline Steps and Tools**

AIRFLOW ORCHESTRATION: Weekly on Mondays

constants.py batch\_api.py transform.py visualize.py

main\_api\_pull.py

# Description of data

The data is from an API hosted by analytics.usa.gov as part of the openGSA initiative. This API has daily updates on the number of visits to federal government websites, including the specific domain visited and the device used (e.g., desktop, tablet, mobile). You can pull a variety of different reports from the reports endpoint. I use the “site” report for this case study, which allows me to pull the data for each individual website domain for each federal agency. The API limits each query to 10,000 data points. The parameters in the API request include limit, page, after, before, and api\_key. I use the python request package to retrieve the data from the API.

An example of the daily website visits data is in the image below. The returned fields are id, date, report\_name, report\_agency, domain, and visits. The data is standardized and so I did not have to perform any cleaning on my end.

**Exhibit 2: Raw Data Snapshot**

**Table

Description automatically generated**

# Details of Install and Configuration

**Step 0: Request api key from open.gsa.gov/api/dap/#getting-started**

I filled out the form below and instantly received an api key in my email. I saved the api key in a key.txt file so I could load it into my python script.

**Exhibit 3: API Key Request Form**

**Graphical user interface, text, application, email

Description automatically generated**

**Step 1: Create Virtual Environment and Install Python Packages**

I created a virtual environment called **airflow\_env** with the following command in my terminal. The remainder of all terminal operations in this document occur within this airflow\_env virtual environment.

conda create --name airflow\_env python=3.9 -y

I installed the needed python packages in this terminal: pyspark, pandas, altair PyMySQL, SQLAlchemy with the following commands in my terminal:

pip install altair

pip install pyspark

pip install pandas

pip install PyMySQL  
pip install SQLAlchemy

**Step 2: Install and Setup Apache Spark**

1. **Download and Install:**
   1. **Java SE Development Kit (JDK):** https://www.oracle.com/java/technologies/javase/jdk19-archive-downloads.html
   2. **Hadoop 3.2.2 binaries:** https://github.com/cdarlint/winutils/tree/master/hadoop-3.2.2/bin
   3. **Spark 3.3.1:** Go to spark.apache.org/downloads.html to download a spark-3.3.1-bin-hadoop3.tgz and untar the file.

I stored these files in my Users/Jess/opt folder as pictured below.

**Exhibit 4: Directory Organization**

Application, table

Description automatically generated

**Step 3: Download MySQL Community Server and setup mysql database:** <https://dev.mysql.com/downloads/mysql/>.

* I created a root user and created a password for the root user in the installation process. Then, I logged into the sql database with the following terminal prompt: sudo mysql -u root -p. I then entered my password.
* I created a database called “websites”
* I then created a table called “visits” with the “Create Table” command with the following specifications to hold the data I will pull from my API.

**SQL COMMANDS in Terminal:**

sudo mysql -u root -p

CREATE DATABASE websites;

use websites;

CREATE TABLE visits (id INT, date DATE, report\_name VARCHAR(500), report\_agency VARCHAR(500), domain VARCHAR(500), visits INT);

describe visits;

**Exhibit 5: Schema of Visits Table**

Table

Description automatically generated

1. **Update .zshrc file as follows:**
   1. JAVA\_HOME, SPARK\_HOME, and HADOOP\_HOME environmental variables.
   2. JAVA\_HOME and SPARK\_HOME to the PATH variable.
   3. /usr/local/mysql location to my PATH variable.

export

JAVA\_HOME="/Library/Java/JavaVirtualMachines/jdk1.8.0\_361.jdk/Contents/Home"

export PATH=$JAVA\_HOME/bin:$PATH

export SPARK\_HOME=/Users/Jess/opt/spark-3.3.1-bin-hadoop3

export PATH=$SPARK\_HOME/bin:$PATH

export PATH=/Users/Jess/opt/scala@2.12/bin:$PATH

export HADOOP\_HOME=/Users/Jess/opt/hadoop-3.2.2

**Exhibit 6: My .zshrc file**

**Graphical user interface, text, application

Description automatically generated**

**Step 3: Install and Setup Apache Airflow**

I do two things to my .zshrc folder. First, I export a filepath for AIRFLOW\_HOME. Second, I ensure my PYSPARK\_DRIVER lines are commented-out so I can run pyspark as a script through spark-submit rather than opening up a jupyter notebook.

# export PYSPARK\_DRIVER\_PYTHON=jupyter

# export PYSPARK\_DRIVER\_PYTHON\_OPTS=’notebook’

I installed Apache Airflow following the documentation’s QuickStart guide (<https://airflow.apache.org/docs/apache-airflow/stable/start.html>). I entered the code from the Quickstart guide below in my terminal, which defines the AIRFLOW\_VERSION as 2.6.0 and PYTHON\_VERSION as 3.9. The CONSTRAINT\_URL downloads constraints needed for the install from github. The install also uses pip install.

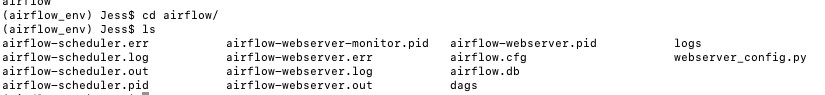
**Exhibit 7: Apache Airflow QuickStart Guide**

Text

Description automatically generated

Now, with airflow installed, I initialize the airflow database with the terminal command: **airflow db init**. This created a directory inside my AIRFLOW\_HOME directory with the files in the image below.

**Exhibit 8: Airflow Folder Contents**



I made a configuration change to the airflow.cfg file to set the “load\_examples=False.” The default is True. When it is set to True, airflow has a bunch of their own examples in the airflow database and I preferred to clear this out.

**Exhibit 9: airflow.cfg file**

Text

Description automatically generated

I then created an airflow use with login credentials with the “users create” terminal command shown below. I can verify that the user was created with the terminal command also below: airflow users list.

**Exhibit 10: Code to Create Airflow User**

Text, letter

Description automatically generated

Diagram

Description automatically generated with medium confidence

Next, I started the airflow web server with the following command. This starts the airflow web server on port 8081. The default port is 8080 if you do not specify a port but I have other processes running on 8080, so I changed the port number.

**airflow webserver -D -p 8081**

I then started the airflow scheduler with the following command:

**airflow scheduler -D**

# Code with comments

I describe my series of code files below.

1. **constants.py**

The constants.py script gets everything setup. It (1) imports python packages I will need (2) defines variables I use as parameters in my api pulls, and (3) prepares Spark to store the data. I import the python packages: requests, json, pandas, pyspark, and datetime. For my api parameters, I import my api key that resides in a text file (key.txt), generate of agencies for which I will request reports, define the api url, and also specify the start and end dates (today’s date and the “pull after” date). Notably, the date parameters are updated for each api batch request. I use the datetime python module to calculate today’s date and the date 7 days prior. This code also defines my Spark session object, tests that Spark is working, and defines a schema for my Spark dataframe that will hold the data.

**Exhibit 11: constants.py script**

*#!/usr/bin/env python  
# coding: utf-8*import requests  
import json  
import pandas as pd  
import pyspark  
from datetime import datetime, timedelta  
from pyspark.sql import SparkSession  
  
''' The constants.py file defines the parameters that we will use in the api pull.  
 This includes the api key, the list of federal agencies for which we will request data,   
 the date range (today and 7 days in the past).   
 The api documentation is at https://open.gsa.gov/api/dap/'''  
  
*# Api key*f = open('/Users/Jess/Documents/e63/apiPull/key.txt', 'r')  
key = f.read()  
  
*# Agencies to query*agencies = ['agency-international-development',  
 'agriculture',  
 'commerce',  
 'defense',  
 'education',  
 'energy',  
 'environmental-protection-agency',  
 'executive-office-president',  
 'general-services-administration',  
 'health-human-services',  
 'homeland-security',  
 'housing-urban-development',  
 'interior',  
 'justice',  
 'labor',  
 'national-aeronautics-space-administration',  
 'national-archives-records-administration',  
 'national-science-foundation',  
 'nuclear-regulatory-commission',  
 'office-personnel-management',  
 'postal-service',  
 'small-business-administration',  
 'social-security-administration',  
 'state',  
 'transportation',  
 'treasury',  
 'veterans-affairs']  
  
*# API URL*url = 'https://api.gsa.gov/analytics/dap/v1.1'  
  
*# pullAfter: This defines the timeframe of the batch data pull (go back 7 days)  
# For example, if today is May 4 when we execute the code, the pullAfter date is April 27.  
# We pull down data from the API from April 27 - May 3.*pullAfter = datetime.now() - timedelta(7)  
pullAfter = datetime.strftime(pullAfter, '%Y-%m-%d')  
print(f'Two Days Ago: {pullAfter}')  
  
*# TODAY'S DATE*today = datetime.today().strftime('%Y-%m-%d')  
print(f'Today: {today}')  
  
*# Schema for Spark Dataframe. Will hold data from API*from pyspark.sql.types import \*  
  
schema = StructType([  
 StructField("id", IntegerType(), True),  
 StructField("date", StringType(), True),  
 StructField("report\_name", StringType(), True),  
 StructField("report\_agency", StringType(), True),  
 StructField("domain", StringType(), True),  
 StructField("visits", IntegerType(), True)  
])  
  
print("Loaded Constants")  
  
*# Spark Session Object*spark = SparkSession.builder.getOrCreate()  
  
*# Show that pyspark is working by printing out "Hello Spark" in a dataframe*df = spark.sql("select 'spark' as hello ")  
df.show()  
  
print("Spark is Setup")

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1. **main\_api\_pull.py**

main\_api\_pull.py is the workhorse that extracts the data from the API. This script imports the constants.py file and defines two functions that pull down the data from the AIP: apiPull() and paginate().

apiPull() requires the parameters page, after, before, and agency to feed into the api request. The parameter “page” determines the page number of the data we are pulling from the API. Since the limit for the api is 10,000 data points per page, we must pull multiple pages when we pull more than 10,000 records for a given agency. The parameter “after” represents the “pullAfter” variable defined in the contants.py file (7 days prior to today). The parameter “before” represents the “today” variable defined in the constants.py file (today’s date). The parameter “agency” represents one agency within the list of agencies defined in the constants.py file.

Within the function, I define the parameters variable, which is a dictionary of all parameters I will feed into the api request. I must use a different api endpoint for each agency. Therefore, I define the endpoint with the agencyReport variable. The response variable holds the results of the api request (url + agencyReport endpoint + parameters), implemented using the python requests package. I return a serialized json object.

paginate() calls the apiPull() function and therefore takes in the parameters apiPull requires in its function signature: after, before, agency. Paginate() loops through all pages of the api endpoint.

First, within paginate, I define a blank Spark dataframe, masterDF, that will hold all the data from all pages. The body of the function is a while loop. I use a while loop to continue to execute a loop as long as the last api request returned data (the length of the data variable is not zero). This allows me to extract all pages of the endpoint. The loop calls the apiPull function and stores the result in the variable “data.” I then execute an “if, else” set of statmements. **If** the last api request returned no data (the length of the data variable is zero) and I return the Spark dataframe. **Else**, I store the data in a new Spark dataframe; append that dataframe to the masterDF with the Spark union() function; and finally increment the “page” parameter by 1 to prepare for the next loop.

**Exhibit 12: main\_api\_pull.py script**

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*#!/usr/bin/env python  
# coding: utf-8  
  
# Step 1: Load constant variables*from constants import \*  
  
*# Step 2: Define functions to pull data from API*def apiPull(page, after, before, agency):  
 *"""Request data from api"""* """  
 Parameters:   
 - page: page number of the request  
 - after: data after which we are requesting data  
 -agency: federal agency for which we are requesting data  
 """  
   
 *# Parameters used in the api request* parameters = {  
 "limit": 10000, *# Limit is 10,000* "page" : page,  
 "after": after,  
 "before": before,  
 "api\_key": key}  
   
 *# Endpoint* agencyReport = '/agencies/' + agency + '/reports/site/data'  
   
 *# Request data* response = requests.get(url + agencyReport, params=parameters)  
  
 print(f'response status code: {response.status\_code}')  
  
 *# Return a list of json objects* return response.json()  
  
  
def paginate(after, before, agency):  
 *"""Loop through all pages until we have all requested data for that agency"""* """  
 Parameters:   
 - after: data after which we are requesting data  
 -agency: federal agency for which we are requesting data  
 """  
  
 masterDF = spark.createDataFrame(data = [], schema = schema) *# initialize blank df* page = 1 *# starting place* data = [1] *# placeholder  
   
 # If the request returned data, keep going* while len(data) != 0:  
 data = apiPull(page, after, before, agency)  
 print(masterDF.count())  
   
 *# If the length of the data returned is 0, stop and return df* if len(data) == 0:  
 print(f'done with {agency}')  
 return masterDF  
   
 *# If the data has a length > 0, append that data to the masterDF  
 # Increment the page count by 1* else:  
  
 df = spark.createDataFrame(data, schema)  
 masterDF = masterDF.union(df)  
 page += 1

1. **historical\_api.py**

The historical\_api.py script pulls down all website visit data for all federal agencies from the last 5 years: from Jan 1, 2019 through April 30, 2023. This large extraction grabs 3,496,620 rows of data. First, historical\_api.py imports constants.py and the main\_api\_pull.py scripts. Then I loop through all agencies in the agency list, calling the paginate() function for each one. I append all the API data for all agencies in a Spark dataframe called allAgencyDF. Then, I write the allAgencyDF to a mysql database, in a table called “visits” that uses the schema I defined in constants.py.

**I run historical\_api.py as a script through spark-submit** and it takes several minutes to run. I navigate to the folder that holds the scripts so I do not need to write a long path to the script. My terminal command is below.

$SPARK\_HOME/bin/spark-submit historical\_api.py

**Exhibit 13: historical\_api.py script**

**­­­­**

*#!/usr/bin/env python  
# coding: utf-8  
  
# Step 1: Load constant variables*from constants import \*  
  
*# Step 2: Load functions we will use to pull down data from API*from main\_api\_pull import \*  
  
*# Step 3: Extract historical data from API: Jan 1, 2019 - April 30, 2023  
# Instantiate Blank DF to hold all data*allAgencyDF = spark.createDataFrame(data=[], schema=schema)  
  
*# Loop through all agencies*for agency in agencies:

*# Pull Data* agencyDF = paginate(after='2019-01-01', before='2023-04-26', agency=agency)  
 print(f'agency count: {agencyDF.count()}')  
 allAgencyDF = allAgencyDF.union(agencyDF)  
  
allAgencyDF.count()  
  
*# Write data to "visits" table in mysql database*allAgencyDF.write \  
 .format("jdbc") \  
 .option("url", "jdbc:mysql://localhost:3306") \  
 .option("dbtable", "websites.visits") \  
 .option("user", "root") \  
 .option("password", "password") \  
 .mode("overwrite").save()

**Exhibit 14: Snips of terminal output for bash run of historical\_api.py**

Graphical user interface, text, application, letter

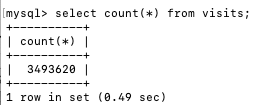
Description automatically generatedTable

Description automatically generated

**Exhibit 15: Partial data from resulting table “visits” after I run historical\_api**

Table

Description automatically generated



A picture containing table

Description automatically generated

1. **batch\_api.py** **(Task 1 Called by Apache Airflow pipeline)**

batch\_api.py is almost same as historical\_api.py, but instead of calling all historical data, it instead dynamically pulls the latest data from the last seven days. This is a script that I will call inside of **Apache Airflow** to implement the data pipeline weekly . Notably, when I write the new batch data to the mysql database table “visits,” I am “appending” the data because we are appending the batch to the historical data already pulled in historical\_api.py. Every weekly batch will keep appending on to this table.

**Exhibit 16: batch\_api.py script**

*# Step 1: Load constant variables*from constants import \*  
  
*# Step 2: Load functions we will use to pull down data from API*from main\_api\_pull import \*  
  
*# Step 3: Pull All Historical Data  
  
# Instantiate Blank DF to hold all data*allAgencyDF = spark.createDataFrame(data = [], schema = schema)  
  
agencies = ['justice']  
*# Loop thorugh all agencies*for agency in agencies:  
  
 *# Pull All Data from Jan 1, 2020 through May 2, 2023* agencyDF = paginate(after=pullAfter, before=today, agency=agency)  
 print(f'agency count: {agencyDF.count()}')  
  
 allAgencyDF = allAgencyDF.union(agencyDF)  
  
allAgencyDF.count()  
  
*# Write data to "visit" table in mysql database*allAgencyDF.write \  
 .format("jdbc") \  
 .option("url","jdbc:mysql://localhost:3306") \  
 .option("dbtable", "websites.visits") \  
 .option("user", "root") \  
 .option("password", "password") \  
 .mode("append").save()

1. **transform.py (Task 2 Called by Apache Airflow pipeline)**

transform.py loads the raw *visits* table from the mysql database into a Spark dataframe called df\_visits. I transform the raw data to monthly counts so it is ready for analysis and visualization. I use a select statement to group the website visits by month. For each agency, I use the sum() function to add together all website visits across all website domains for each month. Then I write the transformed data to a new table in the mysql database called *monthly\_agency*. The write function “overwrites” the *monthly\_agency* table because we need to re-aggregate the data with the new data pull. The monthly\_agency table has one row for each agency for each month of the year.

**Exhibit 17: transform.py script**

import pyspark  
from pyspark.sql import SparkSession  
from pyspark.sql.functions import window, column, desc, col, year, month, dayofmonth  
  
spark = SparkSession.builder.getOrCreate()  
  
*# Show that pyspark is working*df = spark.sql("select 'spark' as hello ")  
df.show()  
  
*# Read in visits data from websites database*df\_visits = spark.read \  
 .format("jdbc") \  
 .option("url","jdbc:mysql://localhost:3306") \  
 .option("dbtable", "websites.visits") \  
 .option("user", "root") \  
 .option("password", "password") \  
 .load()  
  
df\_visits.show(1)  
  
*# Aggregate Table: Agency Visits by Month*monthly\_agency = df\_visits\  
.select(  
 "report\_agency", "visits", "date",  
 year("date").alias('year'),  
 month("date").alias('month'),  
 dayofmonth("date").alias('day'))\  
.groupBy(col("report\_agency"), col("year"), col("month"))\  
.sum("visits").withColumnRenamed("sum(visits)", "visits\_agg").orderBy("report\_agency", "year","month")  
  
monthly\_agency.show(1)  
  
*# Save transformed table into database  
# Over-write stored data*monthly\_agency.write \  
 .format("jdbc") \  
 .option("url","jdbc:mysql://localhost:3306") \  
 .option("dbtable", "websites.monthly\_agency") \  
 .option("user", "root") \  
 .option("password", "password")\  
 .mode("overwrite").save()

1. **visualize.py (Task 3 Called by Apache Airflow pipeline)**

visualize.py loads the data from the mysql database into a pandas dataframe and then visualizes it using the python altair package. First, I installed 3 python packages (PyMySQL, SQLAlchemy, altiar) in to my virtual environment using pip install. I use PyMySQL and SQLAlch to load in the monthly\_agency table from mysql database into a pandas dataframe called df.

I also load in the visits table in order to pull out the last date extracted. I leverage the datetime python package to parse the year, month, and day from the string (dt.year, dt.month, dt.day). I use this information to populate the title of the 2023 chart.

Next, I use the pandas dataframe df as the source data for my altair heatmap chart. The heatmap chart is interactive where you can hover over each square to view its data. Notably, I will have to update this code when we get to 2024. A future improvement to this code would make it fully automated so manual coding changes are not needed in future years. I save the altair chart as an html file so it is ready to be served up on a website.

**Exhibit 18: visualize.py script**

from sqlalchemy import create\_engine  
import pymysql  
import altair as alt  
import pandas as pd  
from datetime import datetime  
  
*# Connect to mysql database*mysql\_string = 'mysql+pymysql://root:password@localhost:3306/websites'  
conn = create\_engine(mysql\_string)  
df = pd.read\_sql('SELECT \* FROM monthly\_agency', con=conn)  
  
*# Get Last Day of Data*df\_raw = pd.read\_sql('SELECT date FROM visits order by date desc limit 1', con=conn)  
datestring = df\_raw.iloc[0,0]  
dt = datetime.strptime(datestring, '%Y-%m-%d')  
print(dt.year, dt.month, dt.day)  
  
*# Create Heatmap and save as html file  
# Will need to update the code when we get to 2024*tooltip=[alt.Tooltip('report\_agency:O', title = 'Agency'),  
 alt.Tooltip('year:O', title = "Year"),  
 alt.Tooltip('month:O', title = 'Month'),  
 alt.Tooltip('visits\_agg:Q', title = 'Monthly Website Visits', format=",.0f")]  
  
chart2019 = alt.Chart(df.loc[df.year==2019], title="Monthly Website Visits in 2019").mark\_rect().encode(  
 alt.X("month:O").title("Month"),  
 alt.Y("report\_agency:O").title("Agency"),  
 tooltip,  
 alt.Color("visits\_agg").legend(title='Monthly Website Visits', format=",.0f"))  
  
chart2020 = alt.Chart(df.loc[df.year==2020], title="2020").mark\_rect().encode(  
 alt.X("month:O").title("Month"),  
 alt.Y("report\_agency:O").title("Agency").axis(labels=False),  
 tooltip,  
 alt.Color("visits\_agg"))  
  
chart2021 = alt.Chart(df.loc[df.year==2021], title="2021").mark\_rect().encode(  
 alt.X("month:O").title("Month"),  
 alt.Y("report\_agency:O").title("Agency").axis(labels=False),  
 tooltip,  
 alt.Color("visits\_agg"))  
  
  
chart2022 = alt.Chart(df.loc[df.year==2022], title="2022").mark\_rect().encode(  
 alt.X("month:O").title("Month"),  
 alt.Y("report\_agency:O").title("Agency").axis(labels=False),  
 tooltip,  
 alt.Color("visits\_agg"))  
  
chart2023 = alt.Chart(df.loc[df.year==2023], title="2023 through " + str(dt.month) + '/' + str(dt.day) + '/' + str(dt.year)).mark\_rect().encode(  
 alt.X("month:O").title("Month"),  
 alt.Y("report\_agency:O").title("Agency").axis(labels=False),  
 tooltip,  
 alt.Color("visits\_agg"))  
  
heatmap = chart2019 | chart2020 | chart2021 | chart2022 | chart2023  
heatmap.save('/Users/Jess/Documents/e63/apiPull/heatmap.html')

1. **api\_dag.py**

The api\_dag.py is the file used by Apache Airflow to schedule the data pipeline job. I must import several airflow functions, including DAG and BashOperator

The dag\_id is ‘api\_dag.’ With the first block of code, I schedule this data pipeline to run once a week, every Monday at 17:30 UTC, defined by the schedule\_interval variable. There are five positions in the syntax: minute, hour, day of month, month, day of the week. The syntax here is the same as for the crontab bash utility. The pipeline starts on a date in the past, arbitrarily April 4, 2023, per the start\_data variable. Catchup=False means that I don’t want the DAG to go back and pull data from the past.

I define three Tasks in the dag via the BashOperator. The BashOperator allows me to submit bash commands. Task 1 (task\_api) runs the batch\_api.py script through the spark-submit bash command. Task 2 (task\_transform) runs the transform.py script through the spark-submit bash command. Task 3 (task\_viz) runs the visualize.py through the python3 bash command.

I set the order of the three tasks with the last statement with the >> statement, first running task\_api, then task\_transform, then task\_viz.

**Exhibit 19: api.dag.py**

import os  
import pandas as pd  
from datetime import datetime  
from airflow.models import DAG  
from airflow.operators.bash import BashOperator  
  
  
with DAG(  
 dag\_id='api\_dag',  
 schedule\_interval='30 17 \* \* 4',  
 start\_date=datetime(year=2022, month=2, day=1),  
 catchup=False  
) as dag:  
 *# 1. Run pyspark script to pull api data and add raw data to database* task\_api = BashOperator(  
 task\_id='run\_pyspark\_api\_script',  
 bash\_command='$SPARK\_HOME/bin/spark-submit /Users/Jess/Documents/e63/apiPull/batch\_api.py'  
 )  
  
 *# 2. Transform data, save transformed data in a database table* task\_transform = BashOperator(  
 task\_id='run\_pyspark\_transform\_script',  
 bash\_command='$SPARK\_HOME/bin/spark-submit /Users/Jess/Documents/e63/apiPull/transform.py'  
 )  
   
 *#3. Visualize data with python altair* task\_viz = BashOperator(  
 task\_id='run\_python\_viz\_script',  
 bash\_command='python3 /Users/Jess/Documents/e63/apiPull/visualize.py'  
 )  
  
 *# Set order of DAG* task\_api >> task\_transform >> task\_viz

# **Demonstration**

I can visualize my dag in the browser at <http://localhost:8081>. It shows my Schedule, the last time it was run, and the next scheduled time it will run. Notably, it shows a previous run in the image below because I did some test runs first by hitting the “play triangle button.” My demonstration is the first batch run of my DAG, happening on Monday, May 8, 2023. When I hover over the info circle, I can see that my next run is scheduled in 24 minutes, at 17:30 UTC on May 8, 2023. This batch run pulls data from May 1 – May 7 because the latest data available from the API is “yesterday.”

**Exhibit 20: Apache Airflow Web Server**

Graphical user interface, text, application, email, website

Description automatically generated

If I click the api\_dag and then hit “Graph”, I can view my Tasks in the order that I specified. I also toggled on the DAG so it is active with the blue toggle button in the upper left.

**Exhibit 21: Airflow Web Server Graph View of api\_dag**

Graphical user interface, text, application, chat or text message

Description automatically generated

Once my DAG ran on May 8, 2023, I pulled down the latest data from May 1 – May 7. A sql query of the visits table shows a total of 3,510,428 rows, which is an additional 13,808 rows of data from the last 7 days.

**Exhibit 22: SQL Queries from “visits” Table (raw data pulled from API)**

Graphical user interface, application

Description automatically generated

In the exhibit below, can also observe the total number of government website visits per year from 2019 through 2023, noting of course that the 2023 data is only through May 7, 2023. There was peak traffic in 2021, which tapered down in 2023. In 2023, the most popular website to visit so far is Heath and Human Services with over 2 billion visits. The next top three are postal service, commerce, and treasury. The bottom two agencies are the

**Exhibit 23: Queries from the “monthly\_agency” table.**

Table

Description automatically generated

Graphical user interface

Description automatically generated with medium confidence

Table

Description automatically generated

The resulting visualization is saved in the “heatmap.html” file as displayed in the exhibit below.

**Exhibit 24: heatmap.html file in directory**

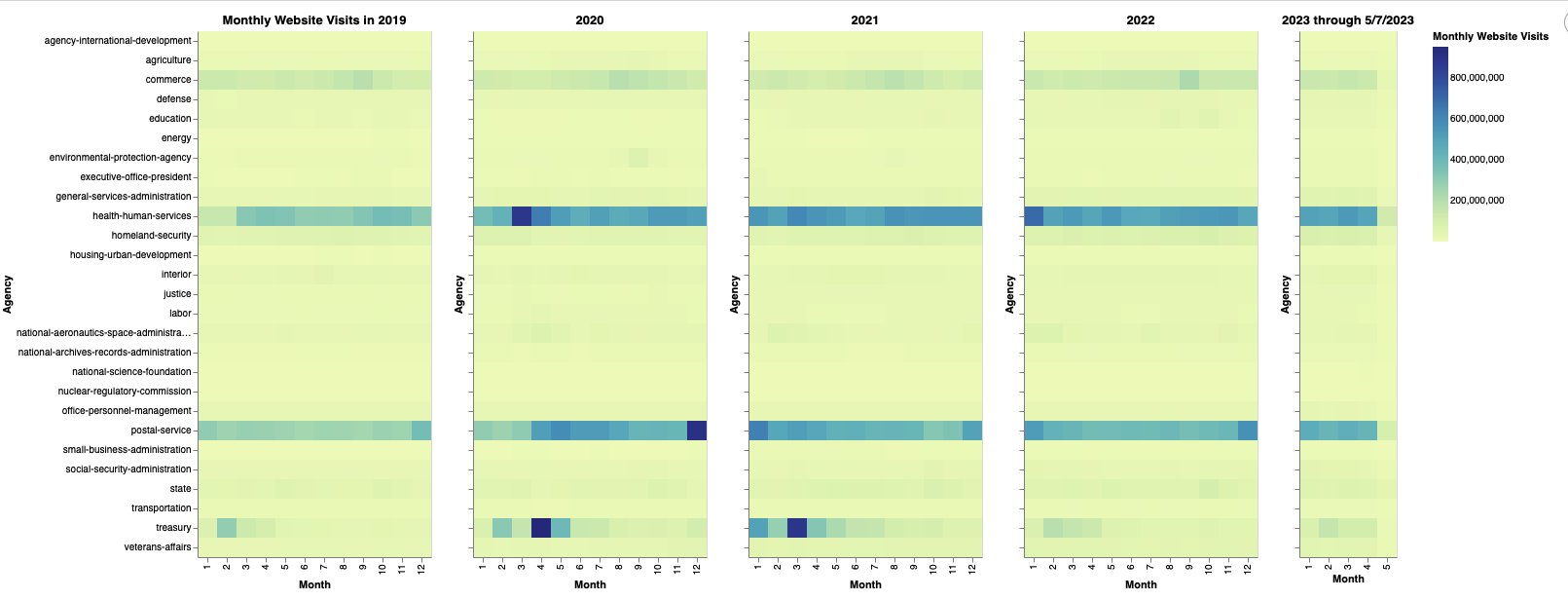
Background pattern

Description automatically generated with medium confidence

As shown in the exhibit on the next page, the visualization in heatmap.html shows all the data through May 7, 2023. The title of the chart automatically also shows this cutoff date. This visualization shows that the websites of the department of health and human services, the postal service, and commerce are the most popular consistently over time. The treasury department has spikes in traffic during the tax season.

In the future, there is an opportunity to dig much more into the data to show individual trends for each agency, and for each agency’s various website domains. I could also pull data from additional API endpoints on the device type for each visitor (e.g., desktop vs mobile). I would also like to integrate additional data sources into the pipeline, including weekly or monthly economic data (e.g., S&P 500, jobs reports) and twitter data to highlight the key conversation topics for each government agency and key influencers.

**Exhibit 25: Heatmap.html**



# Summarize:

**General Lessons Learned:** Start as simple as possible when learning a new tool. Make sure a basic trivial example is working. Then, test every little step of your code and data pipeline before you try to string a pipeline together. I did this both with my API code and with the airflow code.

**Airflow Lesson Learned/Challenges:**

1. If you need to change something in the configuration file airflow.cfg, you have to reset the airflow db (airflow db reset) and also shutdown and restart the webserver and the scheduler. To shutdown the webserver and scheduler, you can use kill <pid>. I got the list of the active pids by running lsof -i tcp:8081. For example, in the image below, I found PID 71088. I used the command “kill 71088” to shutdown the airflow web server.

**Exhibit 26: Command to view active PIDs on port 8081**

A picture containing text

Description automatically generated

1. Airflow uses the UTC timezone for scheduling jobs by default. I was originally thinking it automatically detected my timezone but it does not.
2. If you want your DAG to start running right away at the first opportunity, make sure that your start\_date in your schedule is far enough back. For example, I wanted to run my job weekly at 17:00 UTC every Monday (starting on Monday, May 8, 2023). However, I had my start\_date as May 4, 2023. The job wouldn’t run on Monday, May 8 because it was waiting to start 7 days after my start\_date. I moved my start\_date back to April 4, 2023 and it would run. Here is the article that I read that helped me figure out my problem:

# [Troubleshooting the Apache Airflow Scheduler: DAG Not Triggered at Scheduled Time](https://www.upsolver.com/blog/dag-not-triggered-at-scheduled-time#:~:text=Some%20common%20reason%20DAG%20Not%20Triggered%20at%20Scheduled%20Time%20are%3A,-1.&text=However%2C%20Airflow%20runs%20jobs%20at,than%20at%20the%20scheduled%20time.)

**Pros**: Airflow has a user-friendly visual display of the pipeline. APIs from data.gov offer robust, clean data.

**Cons**: I did not find any specific cons of airflow.

1. Project URLs

**YouTube 2-minute video:** <https://youtu.be/AYaaRbIt7I4>

**YouTube 15-minute video:** <https://youtu.be/CKeJR5OuxSQ>

**git Repo:** [**https://github.com/jhsmith22/e63finalproject.git**](https://github.com/jhsmith22/e63finalproject.git)

# References

**Primary Sources:**

Bill Chambers and Matei Zaharia. “Spark\_The Definitive Guide.” O’Reilly Publisher.

Tutorial on installing apache airflow: <https://betterdatascience.com/apache-airflow-install/>

Tutorial on writing your first apache airflow dag: <https://betterdatascience.com/apache-airflow-write-your-first-dag/>

Apache Airflow Quickstart Guide: <https://airflow.apache.org/docs/apache-airflow/stable/start.html>

**Took a line a code from the following sources:**

https://stackoverflow.com/questions/30483977/python-get-yesterdays-date-as-a-string-in-yyyy-mm-dd-format  
https://stackoverflow.com/questions/32490629/getting-todays-date-in-yyyy-mm-dd-in-python  
<https://stackoverflow.com/questions/62977067/error-while-creating-data-frame-from-rest-api-in-pyspark>

https://softhints.com/convert-mysql-table-pandas-dataframe-python-dictionary/