Introduction to Airflow in Python

Sunday, 29 November 2020 2:24 PM

Intro to Airflow

What is data engineering?

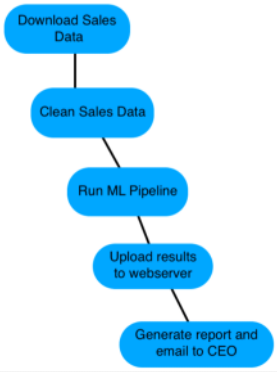
Data engineering is:

- Taking any action involving data and turning it into a reliable, repeatable, and maintainable process.

What is a workflow?

A *workflow* is:

- A set of steps to accomplish a given data engineering task
  - Such as: downloading files, copying data, filtering information, writing to a database, etc
- Of varying levels of complexity
- A term with various meaning depending on context



What is Airflow?

Airflow is a platform to program workflows, including:

- Creation
- Scheduling
- Monitoring

Airflow continued...

- Can implement programs from any language, but workflows are written in Python
- Implements workflows as DAGs: Directed Acyclic Graphs
- Accessed via code, command-line, or via web interface

Other workflow tools

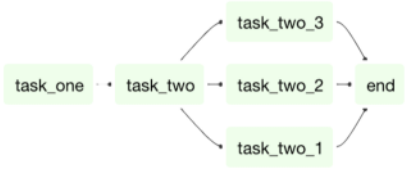
Other tools:

- Luigi
- SSIS
- Bash scripting

Quick introduction to DAGs

A *DAG* stands for *Directed Acyclic Graph*

- In Airflow, this represents the set of tasks that make up your workflow.
- Consists of the tasks and the dependencies between tasks.
- Created with various details about the DAG, including the name, start date, owner, etc.



DAG code example

Simple DAG definition:

```
etl_dag = DAG(
    dag_id='etl_pipeline',
    default_args={"start_date": "2020-01-08"}
)
```

Running a workflow in Airflow

Running a simple Airflow task

```
airflow run <dag_id> <task_id> <start_date>
```

Using a DAG named *example-etl*, a task named *download-file* and a start date of 2020-01-10:

```
airflow run example-etl download-file 2020-01-10
```

What is a DAG?

DAG, or *Directed Acyclic Graph*:

- *Directed*, there is an inherent flow representing dependencies between components.
- *Acyclic*, does not loop / cycle / repeat.
- *Graph*, the actual set of components.
- Seen in Airflow, Apache Spark, Luigi

DAG in Airflow

Within Airflow, DAGs:

- Are written in Python (but can use components written in other languages).
- Are made up of components (typically *tasks*) to be executed, such as operators, sensors, etc.
- Contain dependencies defined explicitly or implicitly.
  - ie, Copy the file to the server before trying to import it to the database service.

Define a DAG

Example DAG:

```
from airflow.models import DAG

from datetime import datetime
default_arguments = {
  'owner': 'jdoe',
  'email': 'jdoe@datacamp.com',
  'start_date': datetime(2020, 1, 20)
}
```

```
etl_dag = DAG( 'etl_workflow', default_args=default_arguments )
```

DAGs on the command line

Using `airflow`:

- The `airflow` command line program contains many subcommands.
- `airflow -h` for descriptions.
- Many are related to DAGs.
- `airflow list_dags` to show all recognized DAGs.

Command line vs Python

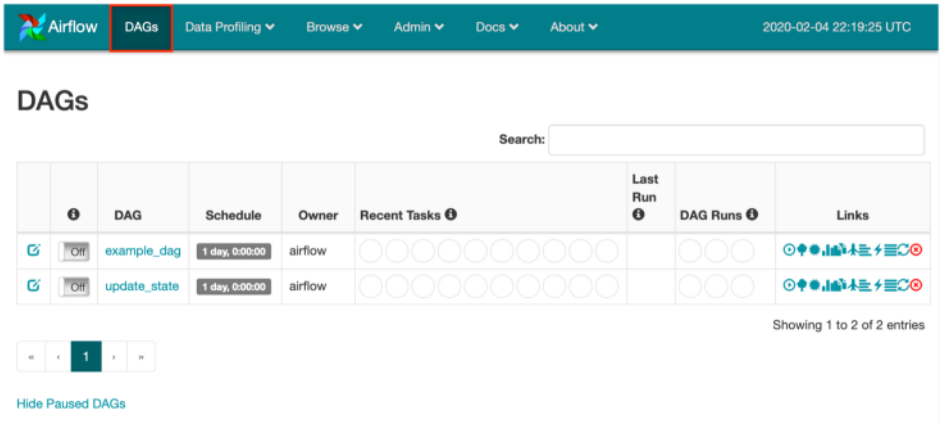
Use the command line tool to:

- Start Airflow processes
- Manually run DAGs / Tasks
- Get logging information from Airflow

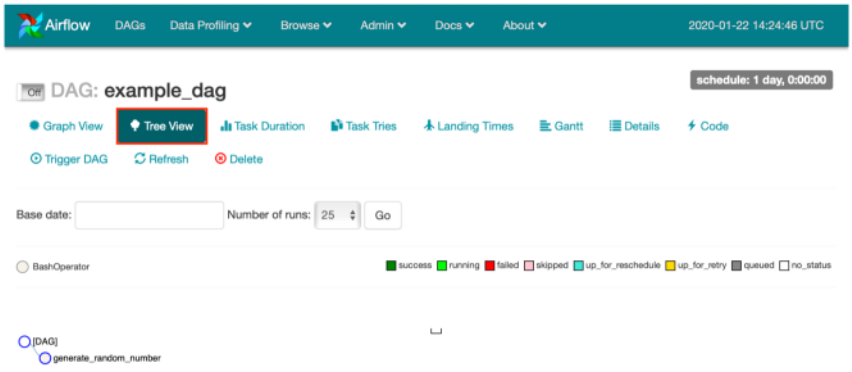
Use Python to:

- Create a DAG
- Edit the individual properties of a DAG

DAGs view

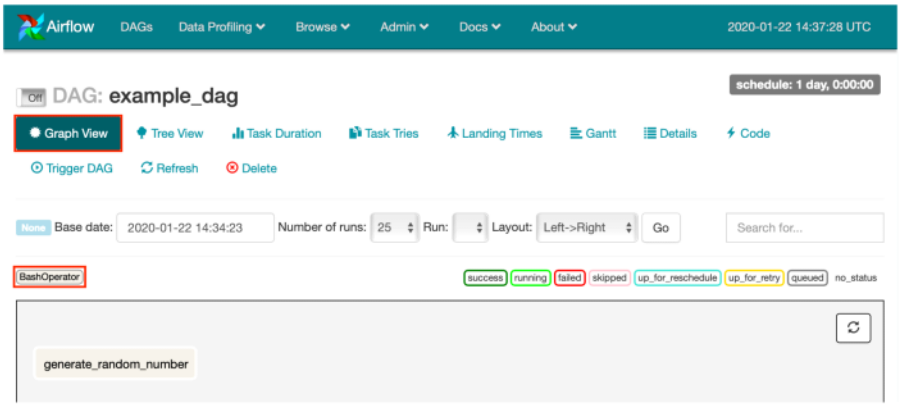


DAG detail view

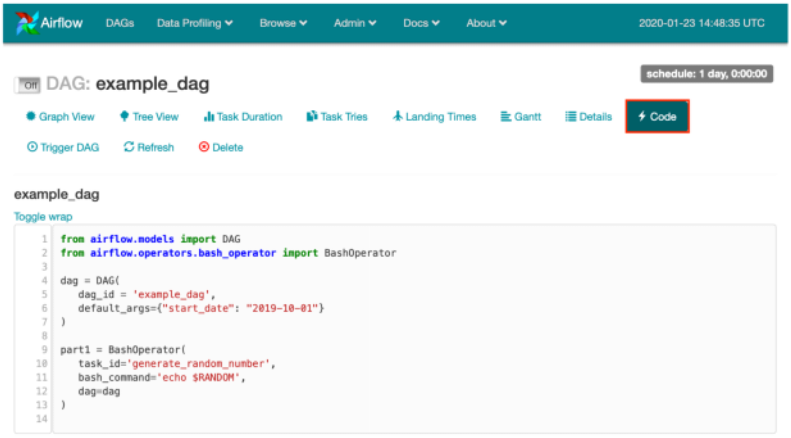


The DAG detail view gives us specific access to information about the DAG itself, including several views of information (Graph, Tree, and Code) illustrating the tasks and dependencies in the code.

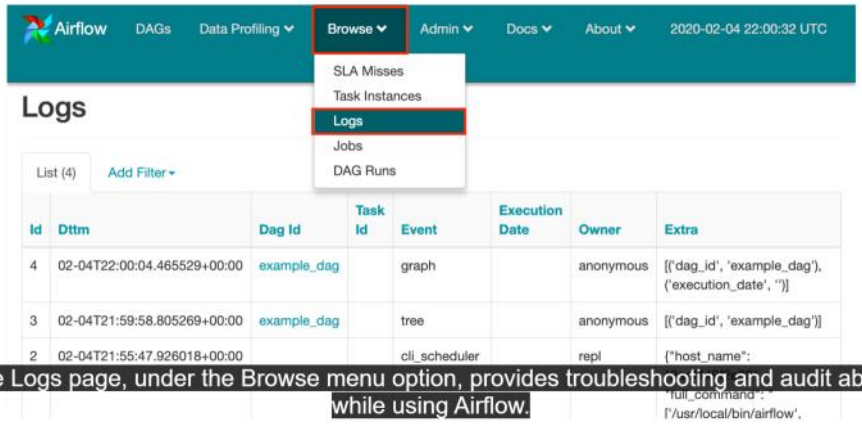
DAG graph view



DAG code view



Logs



The Logs page, under the Browse menu option, provides troubleshooting and audit ability while using Airflow.

Web UI vs command line

In most cases:

- Equally powerful depending on needs
- Web UI is easier
- Command line tool may be easier to access depending on settings

Implementing Airflow DAGs

Operators

- Represent a single task in a workflow.
- Run independently (usually).
- Generally do not share information.
- Various operators to perform different tasks.

```
DummyOperator(task_id='example', dag=dag)
```

For example, the DummyOperator can be used to represent a task for troubleshooting or a task that has not yet been implemented.

BashOperator

```
BashOperator(
    task_id='bash_example',
    bash_command='echo "Example!"',
    dag=ml_dag)
```

- Executes a given Bash command or script.

```
BashOperator(
    task_id='bash_script_example',
    bash_command='runcleanup.sh',
    dag=ml_dag)
```

This command can be pretty much anything Bash is capable of that would make sense in a given workflow.

BashOperator examples

```
from airflow.operators.bash_operator import BashOperator
example_task = BashOperator(task_id='bash_ex',
                            bash_command='echo 1',
                            dag=dag)
```

```
bash_task = BashOperator(task_id='clean_addresses',
  bash_command='cat addresses.txt | awk "NF==10" > cleaned.txt',
  dag=dag)
```

The second example is a BashOperator to run a quick data cleaning operation using cat and awk.

Operator gotchas

- Not guaranteed to run in the same location / environment.
- May require extensive use of Environment variables.
- Can be difficult to run tasks with elevated privileges.

Tasks

Tasks are:

- Instances of operators
- Usually assigned to a variable in Python

```
example_task = BashOperator(task_id='bash_example',
                            bash_command='echo "Example!"',
                            dag=dag)
```

- Referred to by the task_id within the Airflow tools

Task dependencies

- Define a given order of task completion
- Are not required for a given workflow, but usually present in most
- Are referred to as *upstream* or *downstream* tasks

An upstream task means that it must complete prior to any downstream tasks.

- In Airflow 1.8 and later, are defined using the *bitshift* operators
  - >>, or the upstream operator
  - <<, or the downstream operator

Upstream vs Downstream

Upstream means **before**

Downstream means **after**

This means that any upstream tasks would need to complete prior to any downstream ones.

Simple task dependency

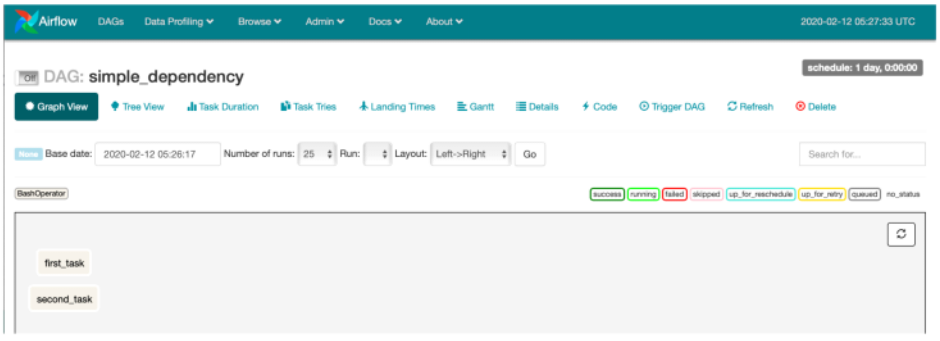
```
# Define the tasks
task1 = BashOperator(task_id='first_task',
                     bash_command='echo 1',
                     dag=example_dag)

task2 = BashOperator(task_id='second_task',
                     bash_command='echo 2',
                     dag=example_dag)

# Set first_task to run before second_task
task1 >> task2   # or task2 << task1
```

operator, two greater-than symbols, as task1 upstream operator task2.

Task dependencies in the Airflow UI



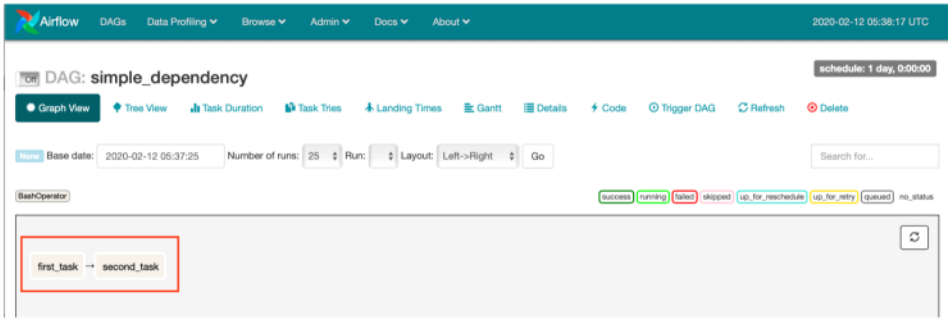
In this case, we're looking at the graph view within the Airflow web interface.

Note that in the task area, our two tasks, first_task and

second_task, are both present, but there is no order to the task execution.

This is the DAG prior to setting the task dependency using the bitshift operator.

Task dependencies in the Airflow UI



Now let's look again at the view with a defined order via the bitshift operators.

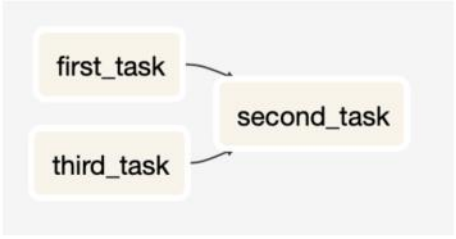
Multiple dependencies

Chained dependencies:

```
task1 >> task2 >> task3 >> task4
```

Mixed dependencies:

```
task1 >> task2 << task3
```



This creates a DAG where first underscore task and third underscore task must finish prior to second underscore task.

or:

```
task1 >> task2
task3 >> task2
```

PythonOperator

- Executes a Python function / callable
- Operates similarly to the BashOperator, with more options
- Can pass in arguments to the Python code

```
from airflow.operators.python_operator import PythonOperator
def printme():
    print("This goes in the logs!")
python_task = PythonOperator(
    task_id='simple_print',
    python_callable=printme,
    dag=example_dag
)
```

Arguments

- Supports arguments to tasks
  - Positional
  - Keyword
- Use the `op_kwargs` dictionary

op_kwargs example

```
def sleep(length_of_time):
  time.sleep(length_of_time)

sleep_task = PythonOperator(
    task_id='sleep',
    python_callable=sleep,
    op_kwargs={'length_of_time': 5}
    dag=example_dag
)
```

Note that the dictionary key must match the name of the function argument.

EmailOperator

- Found in the `airflow.operators` library
- Sends an email
- Can contain typical components
  - HTML content
  - Attachments
- Does require the Airflow system to be configured with email server details

EmailOperator example

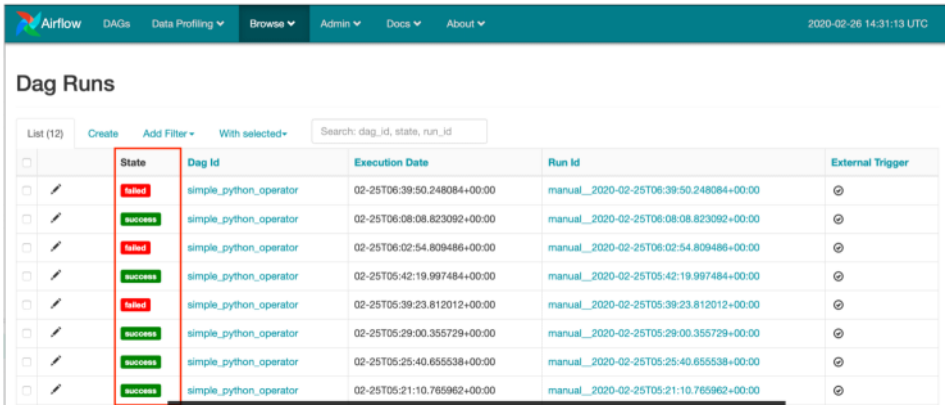
```
from airflow.operators.email_operator import EmailOperator

email_task = EmailOperator(
    task_id='email_sales_report',
    to='sales_manager@example.com',
    subject='Automated Sales Report',
    html_content='Attached is the latest sales report',
    files='latest_sales.xlsx',
    dag=example_dag
)
```

DAG Runs

- A specific instance of a workflow at a point in time
- Can be run manually or via `schedule_interval`
- Maintain state for each workflow and the tasks within
  - `running`
  - `failed`
  - `success`

DAG Runs state



Schedule details

When scheduling a DAG, there are several attributes of note:

- `start_date` - The date / time to initially schedule the DAG run
- `end_date` - Optional attribute for when to stop running new DAG instances
- `max_tries` - Optional attribute for how many attempts to make
- `schedule_interval` - How often to run

Schedule interval

`schedule_interval` represents:

- How often to schedule the DAG
- Between the `start_date` and `end_date`
- Can be defined via `cron` style syntax or via built-in presets.

cron syntax

```
# ┌──────────── minute (0 - 59)
# │ ┌──────────── hour (0 - 23)
# │ │ ┌──────────── day of the month (1 - 31)
# │ │ │ ┌──────────── month (1 - 12)
# │ │ │ │ ┌──────────── day of the week (0 - 6) (Sunday to Saturday;
# │ │ │ │ │                                   7 is also Sunday on some systems)
# │ │ │ │ │
# │ │ │ │ │
# * * * * * command to execute
```

- Is pulled from the Unix cron format
- Consists of 5 fields separated by a space
- An asterisk `*` represents running for every interval (ie, every minute, every day, etc)
- Can be comma separated values in fields for a list of values

cron examples

```
0 12 * * *              # Run daily at noon
```

```
* * 25 2 *              # Run once per minute on February 25
```

```
0,15,30,45 * * * *      # Run every 15 minutes
```

Airflow scheduler presets

Preset:	cron equivalent:
• @hourly	• `0 * * * *`
• @daily	• `0 0 * * *`
• @weekly	• `0 0 * * 0`

Special presets

Airflow has two special `schedule_interval` presets:

- `None` - Don't schedule ever, used for manually triggered DAGs
- `@once` - Schedule only once

schedule_interval issues

When scheduling a DAG, Airflow will:

- Use the `start_date` as the earliest possible value
- Schedule the task at `start_date` + `schedule_interval`

```
'start_date': datetime(2020, 2, 25),
'schedule_interval': @daily
```

This means the earliest starting time to run the DAG is on February 26th, 2020

Maintaining and monitoring Airflow workflows

Sensors

What is a *sensor*?

- An operator that waits for a certain condition to be true
  - Creation of a file
  - Upload of a database record
  - Certain response from a web request
- Can define how often to check for the condition to be true
- Are assigned to tasks

Sensor details

- Derived from `airflow.sensors.base_sensor_operator`
- Sensor arguments:
- `mode` - How to check for the condition
  - `mode='poke'` - The default, run repeatedly
  - `mode='reschedule'` - Give up task slot and try again later
- `poke_interval` - How often to wait between checks
- `timeout` - How long to wait before failing task
- Also includes normal operator attributes

File sensor

- Is part of the `airflow.contrib.sensors` library
- Checks for the existence of a file at a certain location
- Can also check if any files exist within a directory

```
from airflow.contrib.sensors.file_sensor import FileSensor

file_sensor_task = FileSensor(task_id='file_sense',
                              filepath='salesdata.csv',
                              poke_interval=300,
                              dag=sales_report_dag)

init_sales_cleanup >> file_sensor_task >> generate_report
```

Other sensors

- `ExternalTaskSensor` - wait for a task in another DAG to complete
- `HttpSensor` - Request a web URL and check for content
- `SqlSensor` - Runs a SQL query to check for content
- Many others in `airflow.sensors` and `airflow.contrib.sensors`

Why sensors?

Use a sensor...

- Uncertain when it will be true
- If failure not immediately desired
- To add task repetition without loops

You're uncertain when a condition will be true.

If you know something will complete that day but it might

vary by an hour or so, you can use a sensor to check until it is.

If you want to continue to check for a condition but not necessarily fail the entire DAG immediately.

Finally, if you want to repeatedly run a check without adding cycles to your DAG, sensors are a good choice.

What is an executor?

- Executors run tasks
- Different executors handle running the tasks differently
- Example executors:
  - `SequentialExecutor`
  - `LocalExecutor`
  - `CeleryExecutor`

SequentialExecutor

- The default Airflow executor
- Runs one task at a time
- Useful for debugging
- While functional, not really recommended for production

LocalExecutor

- Runs on a single system
- Treats tasks as processes
- *Parallelism* defined by the user
- Can utilize all resources of a given host system

CeleryExecutor

- Uses a Celery backend as task manager
- Multiple worker systems can be defined
- Is significantly more difficult to setup & configure
- Extremely powerful method for organizations with extensive workflows

Determine your executor

- Via the `airflow.cfg` file
- Look for the `executor=` line

```
repl:~$ cat airflow/airflow.cfg | grep "executor = "
executor = SequentialExecutor
repl:~$
```

Determine your executor #2

- Via the first line of `airflow list_dags`
- `INFO - Using SequentialExecutor`

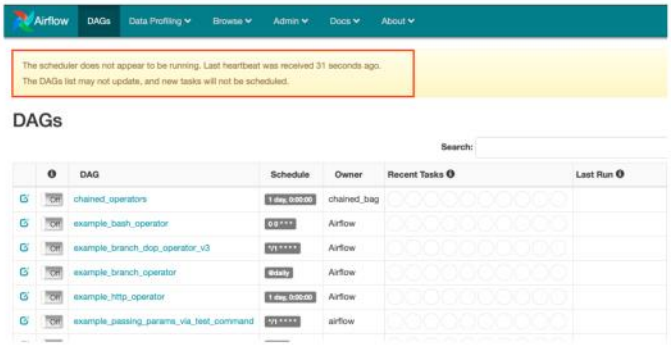
```
repl:~$ airflow list_dags
[2020-04-05 19:29:37,647] {__init__.py:51} INFO - Using executor SequentialExecutor
[2020-04-05 19:29:37,973] {dagbag.py:90} INFO - Filling up the DagBag from /home/repl/workspace/dags
```

Typical issues...

- DAG won't run on schedule
- DAG won't load
- Syntax errors

DAG won't run on schedule

- Check if scheduler is running



- Fix by running `airflow scheduler` from the command-line.

DAG won't run on schedule

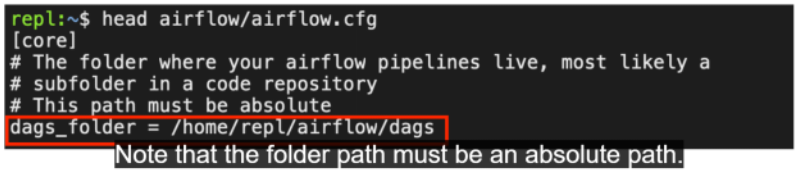
- At least one `schedule_interval` hasn't passed.
  - Modify the attributes to meet your requirements.
- Not enough tasks free within the executor to run.
  - Change executor type
  - Add system resources
  - Add more systems
  - Change DAG scheduling

DAG won't load

- DAG not in web UI
- DAG not in `airflow list_dags`

Possible solutions

- Verify DAG file is in correct folder
- Determine the DAGs folder via `airflow.cfg`
- Note, the folder must be an absolute path



Syntax errors

- The most common reason a DAG file won't appear
- Sometimes difficult to find errors in DAG
- Two quick methods:
  - Run `airflow list_dags`
  - Run `python3 <dagfile.py>`

airflow list_dags

```
repl:~/workspace$ airflow list_dags
[2020-04-08 04:05:55,369] {plugins_manager.py:148} ERROR - name 'BasOperator' is not defined
Traceback (most recent call last):
  File "/usr/local/lib/python3.6/dist-packages/airflow/plugins_manager.py", line 142, in <module>
    m = imp.load_source(namespace, filepath)
  File "/usr/lib/python3.6/imp.py", line 172, in load_source
    module = _load(spec)
  File "<frozen importlib._bootstrap>", line 684, in _load
  File "<frozen importlib._bootstrap>", line 665, in _load_unlocked
  File "<frozen importlib._bootstrap_external>", line 678, in exec_module
  File "<frozen importlib._bootstrap>", line 219, in _call_with_frames_removed
  File "/home/repl/workspace/dags/simple_dependency.py", line 13, in <module>
    task1 = BasOperator(task_id='first_task',
NameError: name 'BasOperator' is not defined
[2020-04-08 04:05:55,370] {plugins_manager.py:149} ERROR - Failed to import plugin /home/repl/workspace/dags/simple_dependency.py
```

Running the Python interpreter

`python3 dagfile.py` :

- With errors

```
(af) mmetzger@hugo:~/airflow/dags$ python3 simple_dependency.py
Traceback (most recent call last):
  File "simple_dependency.py", line 13, in <module>
    task1 = BasOperator(task_id='first_task',
NameError: name 'BasOperator' is not defined
```

- Without errors

```
(af) mmetzger@hugo:~/airflow/dags$ python3 simple_python_operator.py
(af) mmetzger@hugo:~/airflow/dags$
```

If there are no errors, you'll be returned to the command prompt.

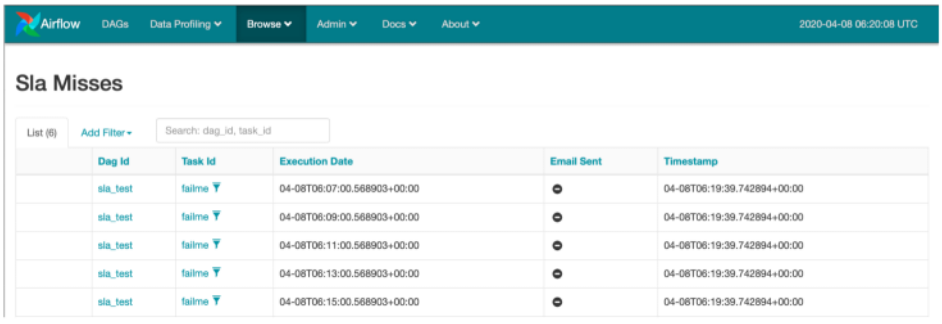
SLAs

What is an SLA?

- An SLA stands for *Service Level Agreement*
- Within Airflow, the amount of time a task or a DAG should require to run
- An *SLA Miss* is any time the task / DAG does not meet the expected timing
- If an SLA is missed, an email is sent out and a log is stored.
- You can view SLA misses in the web UI.

SLA Misses

- Found under Browse: SLA Misses



Defining SLAs

- Using the `'sla'` argument on the task

```
task1 = BashOperator(task_id='sla_task',
                     bash_command='runcode.sh',
                     sla=timedelta(seconds=30),
                     dag=dag)
```

- On the `default_args` dictionary

```
default_args={
 'sla': timedelta(minutes=20)
 'start_date': datetime(2020,2,20)
}
dag = DAG('sla_dag', default_args=default_args)
```

timedelta object

- In the `datetime` library
- Accessed via `from datetime import timedelta`
- Takes arguments of days, seconds, minutes, hours, and weeks

```
timedelta(seconds=30)
timedelta(weeks=2)
timedelta(days=4, hours=10, minutes=20, seconds=30)
```

General reporting

- Options for success / failure / error
- Keys in the default_args dictionary

```
default_args={
  'email': ['airflowalerts@datacamp.com'],
  'email_on_failure': True,
  'email_on_retry': False,
  'email_on_success': True,
  ...
}
```

- Within DAGs from the EmailOperator

Building production pipelines in Airflow

What are templates?

Templates:

- Allow substituting information during a DAG run
- Provide added flexibility when defining tasks
- Are created using the `Jinja` templating language

Non-Templated BashOperator example

Create a task to echo a list of files:

```
t1 = BashOperator(
        task_id='first_task',
        bash_command='echo "Reading file1.txt"',
        dag=dag)
t2 = BashOperator(
        task_id='second_task',
        bash_command='echo "Reading file2.txt"',
        dag=dag)
```

Templated BashOperator example

```
templated_command="""
  echo "Reading {{ params.filename }}"
"""
t1 = BashOperator(task_id='template_task',
       bash_command=templated_command,
       params={'filename': 'file1.txt'}
       dag=example_dag)
```

Output:

```
Reading file1.txt
```

At runtime, Airflow will execute the BashOperator by reading the templated command and replacing params dot filename with the value stored in the params dictionary for the filename key.

Templated BashOperator example (continued)

```
templated_command="""
  echo "Reading {{ params.filename }}"
"""
t1 = BashOperator(task_id='template_task',
       bash_command=templated_command,
       params={'filename': 'file1.txt'}
       dag=example_dag)
t2 = BashOperator(task_id='template_task',
       bash_command=templated_command,
       params={'filename': 'file2.txt'}
       dag=example_dag)
```

Quick task reminder

- Take a list of filenames
- Print "Reading <filename>" to the log / output
- Templated version:

```
templated_command="""
echo "Reading {{ params.filename }}"
"""
t1 = BashOperator(task_id='template_task',
     bash_command=templated_command,
     params={'filename': 'file1.txt'}
     dag=example_dag)
```

More advanced template

```
templated_command="""
{% for filename in params.filenames %}
  echo "Reading {{ filename }}"
{% endfor %}
"""
t1 = BashOperator(task_id='template_task',
       bash_command=templated_command,
       params={'filenames': ['file1.txt', 'file2.txt']}
       dag=example_dag)
```

```
Reading file1.txt
Reading file2.txt
```

Variables

- Airflow built-in runtime variables
- Provides assorted information about DAG runs, tasks, and even the system configuration.
- Examples include:

```
Execution Date: {{ ds }}                              # YYYY-MM-DD
Execution Date, no dashes: {{ ds_nodash }}            # YYYYMMDD
Previous Execution date: {{ prev_ds }}                # YYYY-MM-DD
Prev Execution date, no dashes: {{ prev_ds_nodash }}  # YYYYMMDD
DAG object: {{ dag }}
Airflow config object: {{ conf }}
```

Macros

In addition to others, there is also a `{{ macros }}` variable.

This is a reference to the Airflow macros package which provides various useful objects / methods for Airflow templates.

- `{{ macros.datetime }}` : The `datetime.datetime` object
- `{{ macros.timedelta }}` : The `timedelta` object
- `{{ macros.uuid }}` : Python's `uuid` object
- `{{ macros.ds_add('2020-04-15', 5) }}` : Modify days from a date, this example returns 2020-04-20

Branching

Branching in Airflow:

- Provides conditional logic
- Using `BranchPythonOperator`
- `from airflow.operators.python_operator import BranchPythonOperator`
- Takes a `python_callable` to return the next task id (or list of ids) to follow

Branching example

```
def branch_test(**kwargs):
  if int(kwargs['ds_nodash']) % 2 == 0:
    return 'even_day_task'
  else:
    return 'odd_day_task'

branch_task = BranchPythonOperator(task_id='branch_task',dag=dag,
       provide_context=True,
       python_callable=branch_test)

start_task >> branch_task >> even_day_task >> even_day_task2
branch_task >> odd_day_task >> odd_day_task2
```

Branching graph view

Running DAGs & Tasks

To run a specific task from command-line:

```
airflow run <dag_id> <task_id> <date>
```

To run a full DAG:

```
airflow trigger_dag -e <date> <dag_id>
```

Operators reminder

- BashOperator - expects a `bash_command`
- PythonOperator - expects a `python_callable`
- BranchPythonOperator - requires a `python_callable` and `provide_context=True`. The callable must accept `**kwargs`.
- FileSensor - requires `filepath` argument and might need `mode` or `poke_interval` attributes

Template reminders

- Many objects in Airflow can use templates
- Certain fields may use templated strings, while others do not
- One way to check is to use built-in documentation:

1. Open python3 interpreter
2. Import necessary libraries (ie, `from airflow.operators.bash_operator import BashOperator`)
3. At prompt, run `help(<Airflow object>)`, ie, `help(BashOperator)`
4. Look for a line that referencing *template_fields*. This will specify any of the arguments that can use templates.

Template documentation example

```
repl:~$ python3
Python 3.6.7 (default, Oct 22 2018, 11:32:17)
[GCC 8.2.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> from airflow.operators.bash_operator import BashOperator
>>> help(BashOperator)
```

```
|  ----------------------------------------------------------------------
|  Data and other attributes defined here:
|
|  template_ext = ('.sh', '.bash')
|
|  template_fields = ('bash_command', 'env')
|
|  ui_color = '#f0ede4'
```