Day 12: Scripting Workflows I

Parameter Sweeps
Turn In Homework
Homework Review
Scripting Workflows
The Need for Scripting

• Since Condor runs jobs and manages workflows, why do we even need to script anything?

• Jobs are usually part of much larger workflow
  – Instruments → data → jobs → results → papers → funds!
  – Human tasks: Design experiments, interpret results, …
  – Scripting can assist in these steps

• But even for the jobs…
  – Beforehand: Prepare workflow, jobs, data
  – Afterward: Handle data, clean up
Example

- Queue simulator! Say, for the UW Credit Union

- Vary:
  - Number of tellers: 1–3
  - Arrival rate: 1–60 per hour
  - Allow departures or not

- 360 combinations
  - Each combination is one set of command-line args.
  - 360 arguments and queue statements

- Do you want to set up and submit jobs manually?
Parameter Sweeps
Parameter Sweeps Defined

- Run same code for a range of input values
- Combinations of multiple ranges ($n$ dimensions)

- Defining ranges
  - $Start$ - $stop$ - $step$
    - Are boundaries included?
    - E.g.: 1 to 1000 2–256, evens $[40.0, 80.0]$ by 0.25
  - $Start$ - $stop$ - $count$
    - Are boundaries included?
    - E.g.: 1000 runs from 40.0 up to 60.0
  - $Start$ - $count$ - $step$
    - E.g.: 1000 trials starting at 1200 counting by 10s
Parameter Sweep in One Dimension

- Enumerating all values of a numeric range is easy
- Convert to `start-stop-step` and use `xrange()`
  - Arguments are integers, can convert to float in loop
  - Range stops before `stop`
  - `start` defaults to 0; `step` defaults to 1, can be < 0

```python
for i in xrange(start, stop, step):
  # Calculate real value, if needed
  # Do something with value
```

- Non-numeric ranges use sequences: `list`, `file`, ...

```python
for i in list_of_values:
```
Parameter Sweep in Many Dimensions

- Use nested loops:

```python
for i in parameter_1:
    for j in parameter_2:
        for k in parameter_3:
            # Calculate real value(s)
            # Do something with values
```

- Bank queue example:

```python
for tellers in xrange(1, 4):
    for rate in xrange(2, 120):
        real_rate = rate / 2.0
        run_queue_sim(tellers, real_rate)
```
Data-Driven Code

• Writing loops is easy
• But what happens when you change your design?

• Consider writing generic parameter sweep code
• Actual parameter ranges come from file
• Changing parameters = changing a text file

• This is an example of *data-driven* code:
  – Write general purpose code
  – Vary behavior from outside (files, arguments)
  – Spend less time changing code to use
  – But… make only as general as you need now!
Data-Driven Parameter Sweeps I

• First, design format of parameters in file

```plaintext
# Very simple: Bank queue parameters
tellers, 1, 4, 1
rates, 1.0, 60.0, 0.5
```

• Getting fancier:
  – Different types of parameters
  – More human-friendly syntax

```plaintext
# Way more complex
site: "Site Code" = {ABC, DEF, GHI, JKL}
power: "Power Factor" = [0.0, 1.0) x 0.05
gain: "Gain" = 1-4 ((10 ** _))
```
Data-Driven Parameter Sweeps II

- Write code to read and parse parameter file
- Create sequences for each parameter

```python
params = []
for line in param_file:
    parts = re.split(r'\s*,\s*', line)
    start = int(parts[1])
    stop = int(parts[2])
    step = int(parts[3])
    p_range = xrange(start, stop, step)
    params.append(((parts[0]), p_range))
```
Data-Driven Parameter Sweeps III

• Use iterator function to visit every combination: `itertools.product()` (Python ≥ 2.6), else:

```python
def product(*args):
    pools = map(tuple, args)
    result = [[]]
    for pool in pools:
        result = [x + [y] for x in result for y in pool]
    for prod in result:
        yield tuple(prod)
```

# `pN` is parameter range in sequence type
for `t` in `itertools.product(p1, p2, p3)`:  
# `t` is tuple of parameter values
# Do stuff with this combination
Condor
Overview of Approaches

Assuming that we want to run a Condor job for each combination of parameter values, …

1. Separate submits
2. One submit, many arguments & queue statements
3. One submit, many directories
Separate Submit Files

• How it works:
  – For each combination of parameter values:
  – Write a Condor submit file with all necessary lines
  – Parameter values: arguments statement or input file

• Disadvantages
  – Must submit each job separately
  – Extra overhead
  – Leaves many submit files around
Parameters in Arguments I

• Overview
  – Script creates one huge submit file
  – Each parameter combo gets arguments & queue lines
  – Input, output, error, and log files:
    ✦ All in same directory; files named with $(process)
    ✦ Each in separate directory per $(process)

... arguments "1 20"
queue
arguments "1 21"
queue
...
Parameters in Arguments II

- Put all of the common submit statements in a file:

```
# submit-prefix.txt
executable = sweep.py
universe = vanilla
output = sweep-out/sweep-$(PROCESS).out
error  = sweep-err/sweep-$(PROCESS).err
log    = sweep-log/sweep-$(PROCESS).log

should_transfer_files = YES
when_to_transfer_output = ON_EXIT
```
# Sketch of main script to make submit file

```python
header = read_submit_prefix()  # string
submit = open(filename, 'w')
submit.write(header)

params = read_parameters_file()  # from earlier
for t in product(*params):
    args = ' '.join(t)
    submit.write('arguments = "%s"\n' % args)
    submit.write('queue\n')
submit.close()

if options.submit:
    print 'Submitting job...'  
    os.system('condor_submit ' + filename)
```

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**Parameters in Arguments III**

- `header`: read from `read_submit_prefix()`, string
- `submit`: open file with mode 'w'
- `params`: read from `read_parameters_file()`
- `product(*params)`: for each combination of parameters
  - `args = ' '.join(t)`
  - Write arguments to file
  - Write queue
- `submit.close()`
- `options.submit`: if set, print submission message and use `condor_submit`
Arguments vs. Files

• Parameters via *command-line arguments*
  – When you must, because of the program
  – For few and/or simple parameters

• Parameters via *input files*
  – When you must, because of the program
  – For complex parameters
  – When you must use input files for other reasons
Parameters in Files I

- How it works:
  - Manually write one submit file (details on next slide)
  - For each combination of parameter values, script:
    - Creates a numbered subdirectory
    - Writes template files, possibly modified, into directory
    - Like homework assignment #6
Parameters in Files II

• Write one submit file for all jobs
• Use `initialdir` with `$(PROCESS)` for job subdirs
• Put `queue N` at end (script should modify `N`)

```bash
executable = file-sweep.py
universe = vanilla
initialdir = sweep-$(PROCESS)
output = sweep.out
error = sweep.err
log = sweep.log
should_transfer_files = YES
when_to_transfer_output = ON_EXIT
transfer_input_files = params.txt, ...
queue 1000
```
Parameters in Files III

- Need good function to write modified template file
- Pick parameter placeholder text to avoid conflicts

```python
# Outline of a template writer function
# params: (('p1', 42), ('p1', 43), ...)
def write_template(text, target_name, params):
    for p in params:
        p_name, p_value = p
        p_src = '{:%s}' % p_name
        text = text.replace(p_src, p_value)
    output_file = open(target_name, 'w')
    output_file.write(text)
    output_file.close()
```
Parameters in Files IV

- Read files from template dir into, say, dictionary
- Then, make all directories and files for run

```
# Outline of code to prepare a template run
# sources: dict from filename to contents

def write_job_dirs(sources, count, params):
    for i in xrange(count):  # [0, count)
        dirname = 'sweep-' + str(i)
        os.mkdir(dirname)
        pfile = os.path.join(dirname, 'params.txt')
        write_parameters(params, pfile)
        for filename in sources:
            text = sources[filename]
            target = os.path.join(dirname, filename)
            write_template(text, target, params)
```
Parameters in Files V

- Top-level plan: Read data, write directories and files
- Could also submit Condor job

```python
# Outline of main script

opts, args = parse_command_line()

params = read_parameters(args['param_path'])

sources = read_sources(args['template_dir'])

update_queue_n(params)

write_job_dirs(sources, count, params)

if opts.submit:
    os.system('condor_submit sweep.sub')
```
Output
Harvesting Output

- Need a post-script to gather or consolidate output?
- Without DAGMan, no post-script in job per se
- If this is significant work, use a separate job!

```python
# Assumes all interesting output is from stdout
for outfile in glob.glob('sweep-*/sweep.out'):
    handle_output(outfile)

outfiles = ('sweep.out', 'out1.txt', 'out2.csv')
regexp = r'sweep-\d+$'
for d in os.listdir('.'):  
    if (os.path.isdir(d) and re.match(regexp, d)):  
        for outfile in outfiles:  
            handle_output(d, outfile)
```
Consolidating Output

- Combine all output files into one
- Prefix each line with parameter info
- Need way to recover parameters for each run (maybe write to file when creating run directory?)

```python
combo = open(combined_output_filename, 'w')
for d in run_directories:
    d_params = read_run_params(d)
    d_output = read_run_output(d)
    for line in d_output:
        combo.write('	'.join(d_params) + '	')
        combo.write(line)
combo.close()
```
Cleaning Up

• If running many times, clean up after each run

```python
# Just a sketch of some possibilities

def handle_output(dir, file):
    out_path = os.path.join(dir, file)
    n = re.match(r'sweep-(\d+)$', dir)[1]
    new_file = 'output-%d.txt' % (n)
    new_path = os.path.join('output', new_file)
    shutil.move(out_path, new_path)

for run_dir in run_directories:
    handle_output(run_dir, 'sweep.out')
    shutil.rmtree(run_dir)
```
Homework
Homework

• Make a pretty picture!
• Instead of one long job, break into several smaller jobs… by “tile”
• Lots of background info, read carefully to understand
• For now, stitch resulting image files together manually