Productive Use of the Apache Spark Prompt

Sam Penrose

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- Your ~~teacher~~ fellow student
- Does “data engineering” for Mozilla (distributed, terabyte-scale)
  - Learned by doing, would like to save others time and worry

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We will learn

1. How distributed coding at scale (“DCS”) is new
2. The problems you encounter and their five root causes
   a. Variance, cluster state, algorithms, mental models, data/compute ratio
3. A core technique for interactive DCS coding
   a. Localize problem state to observe it
   b. Scale out and up in steps
4. How to apply the technique

“Productive”: not stuck

“Truck and trainer get stuck on HWY 242” by Oregon Department of Transportation

“Normal” coding

```
>>> def extract_and_transform(d):
...     value = d['field']
...     return float(value)
...
>>> def test():
...     data = [{'field': '1.1'}, {'field': '1.02'}]
...     expected = [1.1, 1.02]
...     actual = map(extract_and_transform, data)
...     assert actual == expected
...
>>> test()
>>>
```

Tests pass—ship it!

```
>>> import json
>>> with open('production_data.json') as f:
...     production_data = json.load(f)
...
>>> loaded = []
>>> for d in production_data:
...     value = extract_and_transform(d)
...     loaded.append(value)
...
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
  File "<stdin>", line 3, in extract_and_transform
TypeError: float() argument must be a string or a number
```

Let's debug interactively

```
>>> def debug_etl_with_print(d):
...     value = d['field']
...     print "value is:", value
...     return float(value)
...
>>> for d in production_data:
...     _ = debug_etl_with_print(d)
...
value is: 1.07
value is: 1.13
value is: None
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
  File "<stdin>", line 4, in debug_etl_with_print
TypeError: float() argument must be a string or a number
```

What did we just do?

1. Noticed the existence of a problem.
2. Modified our code to **display program** state.
3. By observing the program state, identified the problem.
4. (Having identified the problem, immediately conceived its solution.)

How old is this technique?

1989: Python

1970: Unix shell

1962: Lisp REPL

1951: add print statements

Ritchie and Thompson(sitting) at PDP-11 in Bell Labs

No, really: 1951

5-2 Location of mistakes in a program.

It might be thought that a good way of finding errors in a program would be to make the machine proceed order by order under the control of the "Single E.P." button (see Section 6-4), and to study the numbers in the machine by watching the monitors attached to the arithmetical unit and store. This, however, usually turns out to be a very slow and inefficient process, especially as the numbers are displayed in binary form. Methods have therefore been developed which permit the machine to proceed unhindered by the operator, whilst printing on the teleprinter a permanent record that can be studied at leisure, and that will assist in understanding the nature of the mistake.

One such method is to wait until the machine has stopped (or to stop it deliberately) and then, without clearing the whole store, to insert (by pressing the starter button again) a small program which will print, in suitable form, the contents of part of the store. This has come to be known as the "post-mortem" method. Tapes are kept available near the EDSAC for printing the function letters, or address parts, of orders in consecutive storage locations. Programmers may also prepare their own post-mortem tapes.

This method yields only a static picture of the store as it was when the calculation stopped. Other methods have been derived to provide information about the whole course of the calculation. These necessarily involve modifying the program to cause the extra printing, and therefore a new tape must be prepared and presented to the machine. This, however, is no hardship, since the machine will read an average tape in about a minute, and the preparation need not take more than a few minutes of the programmer's time.

5-21 Method using extra output orders. One simple and very useful plan is to place an output order at the beginning of the master routine and in front of each subroutine so that the completion of the various stages of the program

The Preparation of Programs for an Electronic Digital Computer, Maurice Wilkes, 1951

Notebooks: brave new (?) world

```
>>> import json
>>> with open('production_data.json') as f:
...     production_data = json.load(f)
...
>>> loaded = []
>>> for d in production_data:
...     value = extract_and_transform(d)
...     loaded.append(value)
...
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
  File "<stdin>", line 3, in extract_and_transform
TypeError: float() argument must be a string or a number
```

jupyter Not just Python, stateful Python in a Web Page! Last Checkpoint: 05/26/2017 (autosaved)

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Code CellToolbar

In [1]:
```
def extract_and_transform(d):
    value = d['field']
    return float(value)
```

In [2]:
```
import json
with open('/Users/spenrose/production_data.json') as f:
    production_data = json.load(f)
loaded = []
for d in production_data:
    value = extract_and_transform(d)
    loaded.append(value)
```

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-2-4366f9deab51> in <module>()
      4 loaded = []
      5 for d in production_data:
----> 6     value = extract_and_transform(d)
      7     loaded.append(value)

<ipython-input-1-71e89f87416b> in extract_and_transform(d)
      1 def extract_and_transform(d):
      2     value = d['field']
----> 3     return float(value)

TypeError: float() argument must be a string or a number
```

Coding: 1951 -> 201x

1. Run
2. Observe
3. Edit
    a. GOTO: 1

2017: 2 lines -> 500TB on 30 nodes

jupyter pyspark-notebook Last Checkpoint: 17 hours ago (autosaved)

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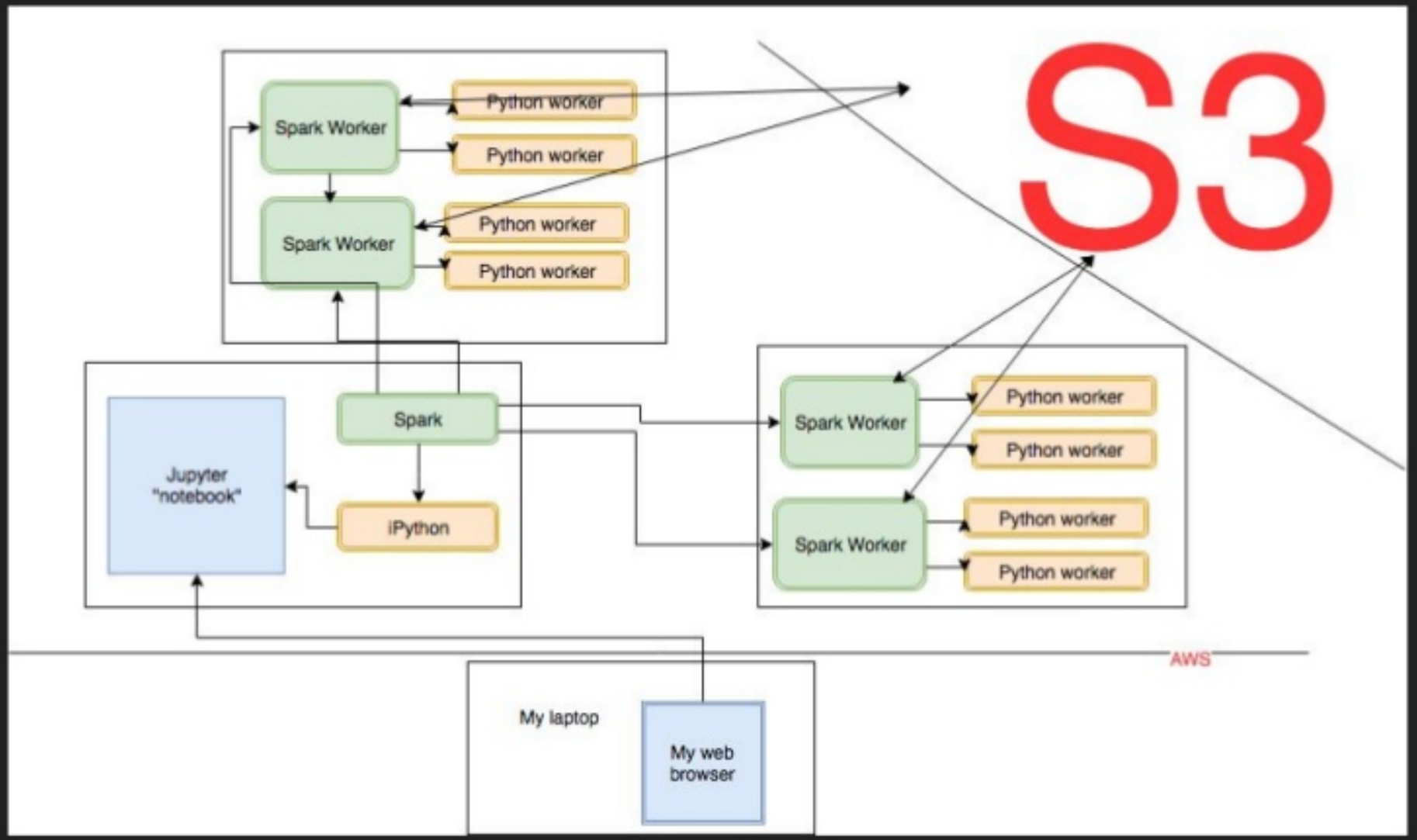
Code CellToolbar

In [1]:
```
DATA_PATH = 's3://telemetry-parquet/main_summary/v4/'
main_summary = sqlContext.read.parquet(DATA_PATH)
```

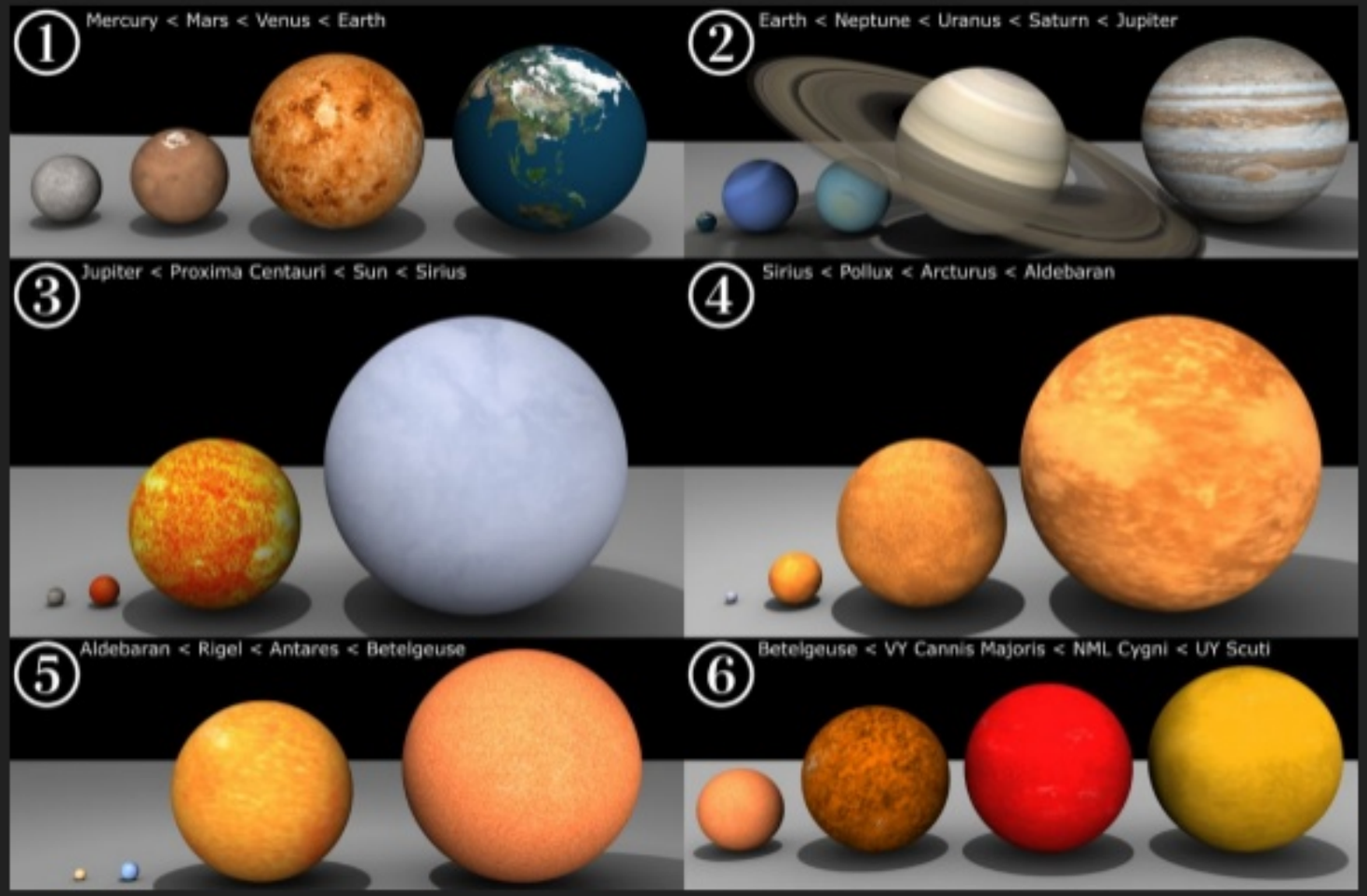
Brave new world

1. EDSAC -> Lisp -> Unix -> Python -> Jupyter: “normal” coding
2. Map / Reduce -> Spark -> AWS -> Distributed computing at scale (“DCS”)
3. **DSC is a brave new world**

Everything has changed … except the UI



Our minds don’t do scale



“Relative sizes of the planets in the solar system and some of the largest stars” by Jcpag2012

Not Python (or Scala), not a variable, not printable

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Code CellToolbar

```
In [1]: DATA_PATH = 's3://telemetry-parquet/main_summary/v4/'
        main_summary = sqlContext.read.parquet(DATA_PATH)

In [3]: main_summary

Out[3]: DataFrame[document_id: string, client_id: string, channel: string, normalized_channel: string
        , country: string, city: string, os: string, os_version: string, os_service_pack_major: bigin
        t, os_service_pack_minor: bigint, windows_build_number: bigint, windows_ubr: bigint, install_
        year: bigint, profile_creation_date: bigint, subsession_start_date: string, subsession_length
        : bigint, distribution_id: string, submission_date: string, sync_configured: boolean, sync_co
        unt_desktop: int, sync_count_mobile: int, app_build_id: string, app_display_version: string,
        app_name: string, app_version: string, timestamp: bigint, env_build_id: string, env_build_ver
        sion: string, env_build_arch: string, e10s_enabled: boolean, e10s_cohort: string, locale: str
        ing, active_experiment_id: string, active_experiment_branch: string, reason: string, timezone
        _offset: int, plugin_hangs: int, aborts_plugin: int, aborts_content: int, aborts_gmplugin: in
        t, crashes_detected_plugin: int, crashes_detected_content: int, crashes_detected_gmplugin: in
        t, crash_submit_attempt_main: int, crash_submit_attempt_content: int, crash_submit_attempt_pl
        ugin: int, crash_submit_success_main: int, crash_submit_success_content: int, crash_submit_su
```

Enormously powerful pseudo-statements

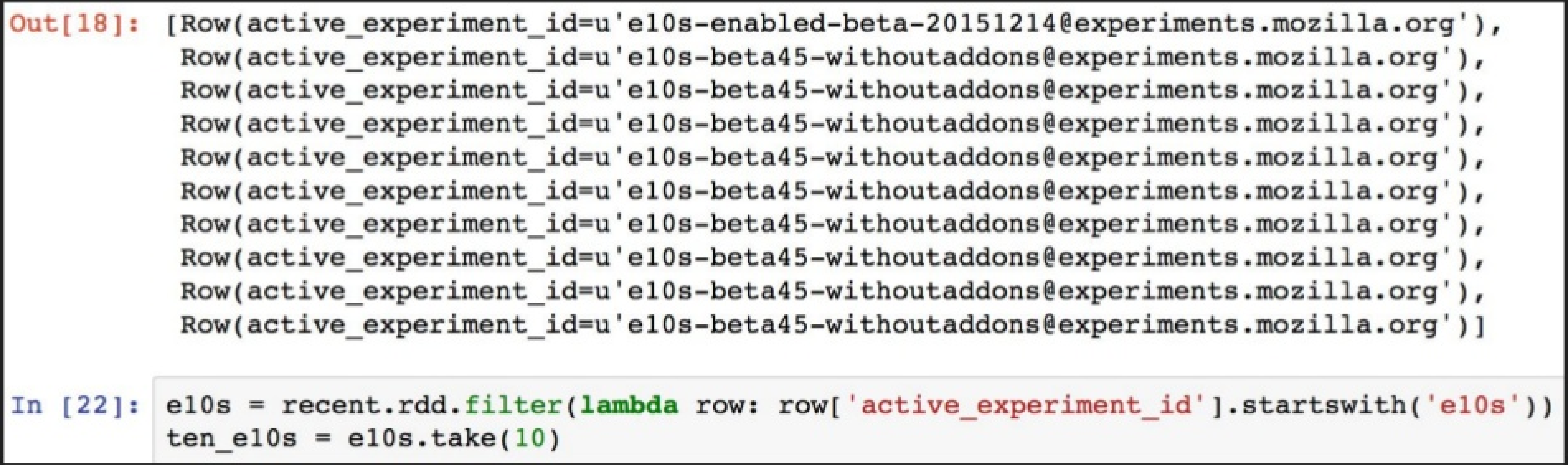
```
In [5]: from datetime import date, timedelta
        week_ago = date.today() - timedelta(days=7)
        start = week_ago.isoformat()
        clause = "submission_date > '{}'".format(start)
        recent = main_summary.where(clause)

In [6]: recent.count()

Out[6]: 53866405276
```

Cognitive dissonance

```
In [5]: from datetime import date, timedelta
        week_ago = date.today() - timedelta(days=7)
        start = week_ago.isoformat()
        clause = "submission_date > '{}'".format(start)
        recent = main_summary.where(clause)

In [6]: recent.count()

Out[6]: 53866405276

In [7]: main_summary.count()

Out[7]: 164284288426
```

Wait, 1/3 of data in last week?
Something's wrong.

Using the DCS[1] prompt: take()



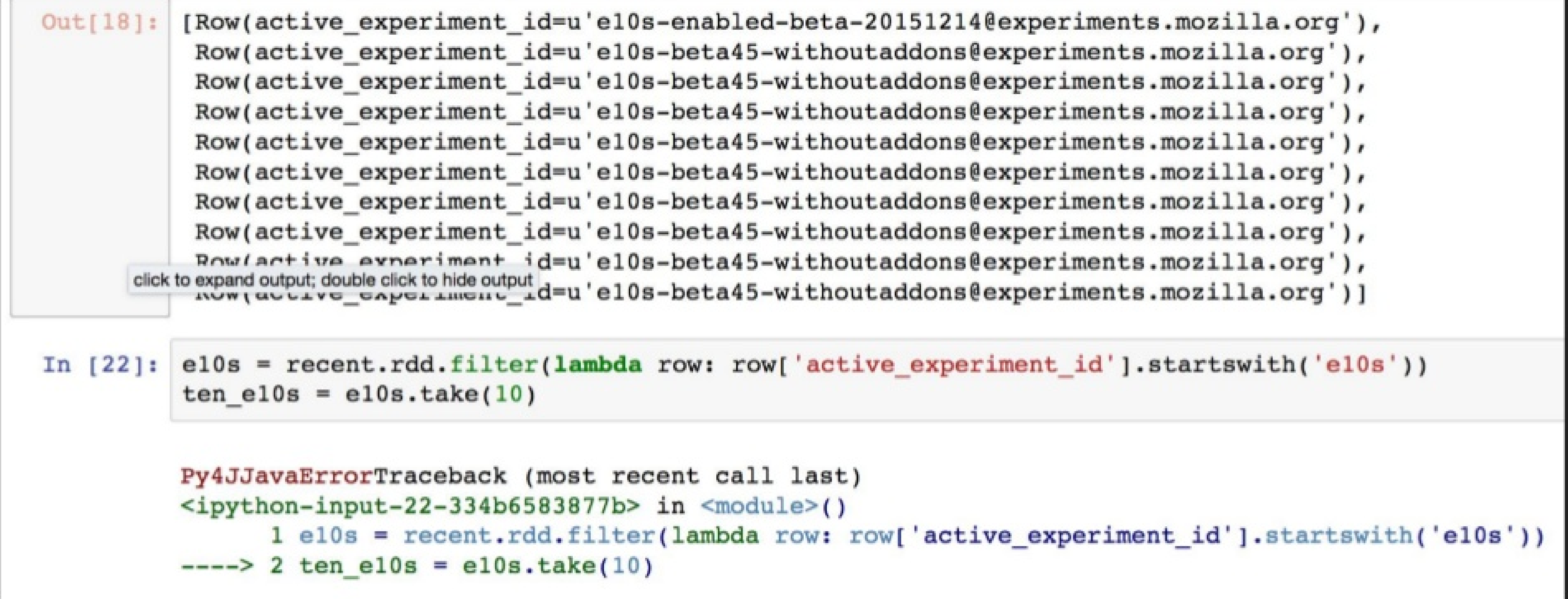
```
Out[18]: [Row(active_experiment_id=u'e10s-enabled-beta-20151214@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org')]
```

```
In [22]: e10s = recent.rdd.filter(lambda row: row['active_experiment_id'].startswith('e10s'))
         ten_e10s = e10s.take(10)
```

---

1. “DCS”: distributed computing at scale

Tracebacks at the DCS prompt (1)



```
Out[18]: [Row(active_experiment_id=u'e10s-enabled-beta-20151214@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org'),
          Row(active_experiment_id=u'e10s-beta45-withoutaddons@experiments.mozilla.org')]
```

```
In [22]: e10s = recent.rdd.filter(lambda row: row['active_experiment_id'].startswith('e10s'))
         ten_e10s = e10s.take(10)
```

```
Py4JJavaErrorTraceback (most recent call last)
<ipython-input-22-334b6583877b> in <module>()
      1 e10s = recent.rdd.filter(lambda row: row['active_experiment_id'].startswith('e10s'))
----> 2 ten_e10s = e10s.take(10)
```

Tracebacks at the DCS prompt (2)

Tracebacks at the DCS prompt (3)

```
  File "<ipython-input-22-334b6583877b>", line 1, in <lambda>
AttributeError: 'NoneType' object has no attribute 'startswith'
```

This reminds me of something ...

```
  File "<ipython-input-22-334b6583877b>", line 1, in <lambda>
AttributeError: 'NoneType' object has no attribute 'startswith'
```

```
>>> import json
>>> with open('production_data.json') as f:
...     production_data = json.load(f)
...
>>> loaded = []
>>> for d in production_data:
...     value = extract_and_transform(d)
...     loaded.append(value)
...
Traceback (most recent call last):
  File "<stdin>", line 2, in <module>
  File "<stdin>", line 3, in extract_and_transform
TypeError: float() argument must be a string or a number
```

Root cause #1: data variance

```
In [16]: def is_e10s_experiment(row):
             if row['active_experiment_id'] is None:
                 return False
             return row['active_experiment_id'].startswith('e10s')
         e10s = recent.rdd.filter(is_e10s_experiment)
         ten_e10s = e10s.take(10)

In [17]: ten_e10s[0]['active_experiment_id']

Out[17]: u'e10s-beta45-withoutaddons@experiments.mozilla.org'
```

Why was I able to debug that?

Did I display the program state? **No.**

Ritchie and Thompson(sitting) at PDP-11 in Bell Labs

What about the previous issue?

```
In [5]: from datetime import date, timedelta
        week_ago = date.today() - timedelta(days=7)
        start = week_ago.isoformat()
        clause = "submission_date > '{}'".format(start)
        recent = main_summary.where(clause)

In [6]: recent.count()

Out[6]: 53866405276

In [7]: main_summary.count()

Out[7]: 164284288426
```

Wait, 1/3 of data in last week?
Something's wrong.

Maybe I can do something about that, too!

```
Wait, 1/3 of data in last week?
Something's wrong.

In [8]: tinytinylittleeensyweensybit = main_summary.take(10)

In [9]: for row in tinytinylittleeensyweensybit:
            print row['submission_date'],

20160620 20160620 20160620 20160620 20160620 20160620 20160620 201

In [10]: start

Out[10]: '2017-05-19'

In [11]: properly_formatted = week_ago.isoformat().replace('-', '')
         properly_formatted

Out[11]: '20170519'

In [12]: clause = "submission_date > '{}'".format(properly_formatted)
         recent = main_summary.where(clause)

In [13]: recent.count()

Out[13]: 2119866345
```

Why was I able to debug these two problems?

1. ~~I displayed the **DCS program state**.~~
2. In the first case, the traceback **displayed the problem**.
3. In the second case, the **problem was displayable** in every row.

You cannot display the state of DCS programs

… but you don’t have to. Instead, use the **core technique**:

1. **Localize** the **problem** state to observe it.

Problem states, localized and observed

```
  File "<ipython-input-22-334b6583877b>", line 1, in <lambda>
AttributeError: 'NoneType' object has no attribute 'startswith'
```

```
Wait, 1/3 of data in last week?
Something's wrong.

In [8]: tinytinylittleeensyweensybit = main_summary.take(10)

In [9]: for row in tinytinylittleeensyweensybit:
            print row['submission_date'],

        20160620 20160620 20160620 20160620 20160620 20160620 20160620 201

In [10]: start

Out[10]: '2017-05-19'

In [11]: properly_formatted = week_ago.isoformat().replace('-', '')
         properly_formatted

Out[11]: '20170519'

In [12]: clause = "submission_date > '{}'".format(properly_formatted)
         recent = main_summary.where(clause)

In [13]: recent.count()

Out[13]: 2119866345
```

Modularize fix, because software engineering

```
In [16]: def is_e10s_experiment(row):
             if row['active_experiment_id'] is None:
                 return False
             return row['active_experiment_id'].startswith('e10s')
         e10s = recent.rdd.filter(is_e10s_experiment)
         ten_e10s = e10s.take(10)

In [17]: ten_e10s[0]['active_experiment_id']

Out[17]: u'e10s-beta45-withoutaddons@experiments.mozilla.org'
```

hadoop@i...-31-0-97:~ | bash | ... | java

File Edit Options Buffers Tools Python Help

```
def is_e10s_experiment(row):
    if row['active_experiment_id'] is None:
        return False
    return row['active_experiment_id'].startswith('e10s')
```

Test, because software engineering

```
In [19]: # Modularize and test module locally
         import my_local_utilities
         worked = filter(my_local_utilities.is_e10s_experiment,
                         tinytinylittleeensyweensybit) == []
         worked

Out[19]: True
```

Engineering problem (1)

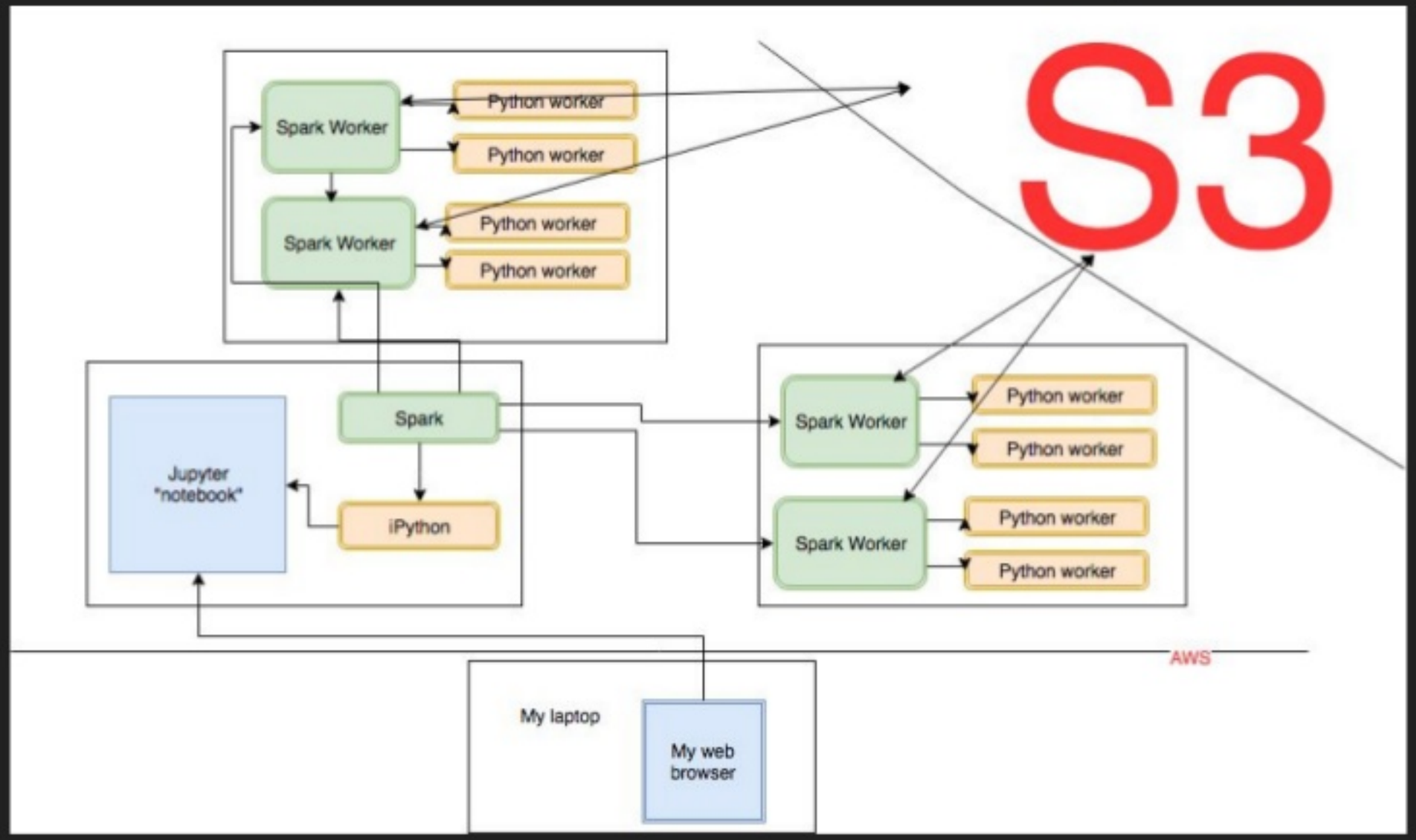
```
In [20]: # Now distribute *the test data* and try the code on it.
         tiny_distributed = sc.parallelize(tinytinylittleeensyweensybit)
         works_distributed = tiny_distributed.filter(
             my_local_utilities.is_e10s_experiment).collect() == []

         Py4JJavaErrorTraceback (most recent call last)
         <ipython-input-20-db53628f212c> in <module>()
               2 tiny_distributed = sc.parallelize(tinytinylittleeensyweensybit)
               3 works_distributed = tiny_distributed.filter(
         ----> 4     my_local_utilities.is_e10s_experiment).collect() == []
```

click to scroll output; double click to hide

Engineering problem (2)

```
Py4JJavaError: An error occurred while calling z:
.
: org.apache.spark.SparkException: Job aborted du
led 4 times, most recent failure: Lost task 0.3 i
s-west-2.compute.internal): org.apache.spark.api.
nt call last):
  File "/mnt/yarn/usercache/hadoop/appcache/appli
12025_0001_01_000164/pyspark.zip/pyspark/worker.p
    func, profiler, deserializer, serializer = re
  File "/mnt/yarn/usercache/hadoop/appcache/appli
12025_0001_01_000164/pyspark.zip/pyspark/worker.p
    command = serializer._read_with_length(file)
  File "/mnt/yarn/usercache/hadoop/appcache/appli
12025_0001_01_000164/pyspark.zip/pyspark/serializ
    return self.loads(obj)
  File "/mnt/yarn/usercache/hadoop/appcache/appli
12025_0001_01_000164/pyspark.zip/pyspark/serializ
    return pickle.loads(obj)
ImportError: No module named my_local_utilities
```

I just imported it … locally



Root cause #2: cluster state

```
In [19]: # Modularize and test module locally
         import my_local_utilities
         worked = filter(my_local_utilities.is_e10s_experiment,
                         tinytinylittleeensyweensybit) == []
         worked

Out[19]: True
```

```
In [20]: # Now distribute *the test data* and try the code on it.
         tiny_distributed = sc.parallelize(tinytinylittleeensyweensybit)
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             my_local_utilities.is_e10s_experiment).collect() == []

         Py4JJavaErrorTraceback (most recent call last)
         <ipython-input-20-db53628f212c> in <module>()
               2 tiny_distributed = sc.parallelize(tinytinylittleeensyweensybit)
               3 works_distributed = tiny_distributed.filter(
         ----> 4     my_local_utilities.is_e10s_experiment).collect() == []
```

click to scroll output; double click to hide

A core technique for interactive DCS

1. **Localize problem** state to observe it.
2. Scale out and up in **steps**.

Scaling out and up in steps

1. Get the code working with a small local dataset.
2. Scale **out**: distribute **that small local dataset** and **that code**. Still works?
3. Scale **up**: iteratively run that code on more and more of the full dataset.
    a. E.g. 1%, 10%, 20%, 40%
    b. On each loop, look for a **scale fail**.

Mo’ data, mo’ problems

Three flavors of scale fail:

1. Traceback reporting a **your-code-vs-your-data** problem.
2. Exponential **slowdown**.
3. Traceback reporting a **toolchain panic**.

Your code vs. your data: “only bring me sorrow”

```
In [14]: def fragile_is_e10s_experiment(row):
             """I will raise an AttributeError."""
             return row['active_experiment_id'].startswith('e10s')
         def is_this_row_naughty(row):
             try:
                 row['active_experiment_id'].startswith('e10s')
             except AttributeError:
                 return True # or row
             return False
         problem_rows = recent.rdd.filter(is_this_row_naughty)
         problem_made_locally_observable = problem_rows.take(10)
```

Root cause #3: mental models of control flow

```
def to_sessions((client_id, pinglist)):
    client = {
        'client_id': client_id,
        'known_bad_pings': [],
        'sessions': [],
        'breaks_by_psc': 0,
        'breaks_by_ssid': 0,
        'breaks_by_sid': 0
        }
    def mark_is_finished(session):
        try:
            session['to_end'] = session['pings'][-1]['meta']['reason'] in ("shutdown", "aborted-session")
            session['complete'] = session['from_start'] and session['to_end']
        except Exception:
            session['to_end'] = False
            session['complete'] = False
    def make_session(first, previousSessionId=None):
        session = {'pings': [first]}
        try:
            session['from_start'] = first.get('payload', {}).get('info', {}).get(
                'subsessionCounter') == 1
        except Exception:
            session['from_start'] = False
        mark_is_finished(session)
        if previousSessionId:
            if first['payload']['info']['previousSessionId'] != previousSessionId:
                client['breaks_by_sid'] += 1
        return session
    def psc(d):
        result = -99
        try:
            result = d.get('payload', {}).get('info', {}).get(
                'profileSubsessionCounter', result)
        except Exception:
            pass
        return result
    pinglist.sort(key=psc)
    previous = pinglist[0]
    session = make_session(previous)
    if not pinglist[1:]:
        mark_is_finished(session)
        client['sessions'].append(session)
    for d in pinglist[1:]:
        try:
            if previous['payload']['info']['profileSubsessionCounter'] + 1 != \
                d['payload']['info']['profileSubsessionCounter']:
                client['breaks_by_psc'] += 1
            if previous['payload']['info']['subsessionId'] != \
                d['payload']['info']['previousSubsessionId']:
                client['breaks_by_ssid'] += 1
            if previous['payload']['info']['sessionId'] == \
                d['payload']['info']['sessionId']:
                session['pings'].append(d)
            else:
                mark_is_finished(session)
                client['sessions'].append(session)
                session = make_session(d, previous['payload']['info']['sessionId'])
            previous = d
        except Exception:
            client['known_bad_pings'].append(d)

    return client
```

If the results surprise you, quantify the control flow

You have a mental model of the control flow. If it's wrong, that could be the problem. Localize and observe it.

```
In [21]: def quantify_control_flow():
             almost_every_time = sc.accumulator(0)
             once_in_a_blue_moon = sc.accumulator(0)
             def process(row):
                 if row['active_experiment_id'] is not None:
                     almost_every_time.add(1)
                     pass # Do the real work.
                 else:
                     once_in_a_blue_moon.add(1)
                     pass
             return process, almost_every_time, once_in_a_blue_moon
         quantifer, almost_every_time, once_in_a_blue_moon = quantify_control_flow()

In [22]: _ = recent.rdd.map(quantifer).collect()

In [23]: print almost_every_time # -> "should" be huge, is tiny
         print once_in_a_blue_moon # "should" be tiny, is huge

         12781730
         2107084615
```

Slowness

Two new root causes:

- #4: exponential algorithm / heuristic
- #5: heavy ratio of data to computational resources

Reallocate

1. Are you comparing every row to every row?
2. Yes: you are (probably) running an exponential algorithm.
   a. First step: repartition on the comparison key(s).
   b. (Make sure the algorithm lacks “inner loop: fetch_across_network()”)
3. No: see if the data is skewed

Repartition on your comparison key

```
def partitioner(d):
    return hash(d.get('meta', d).get('clientId', 'MISSING'))
def get_key(d):
    return d.get('meta', d).get('clientId', 'MISSING')
PARTITION_FACTOR = 10
def group_by_client_id(rdd):
    size = rdd.getNumPartitions() * PARTITION_FACTOR
    rdd.repartitionAndSortWithinPartitions(size, partitioner, True, get_key)
    return rdd.groupBy(lambda d: d.get('clientId', 'MISSING'))
```

Divide and conquer

1. Is your processing function associative?
2. If so, turn that frown upside down!
   a. data*2 -> delay*4 :-(
   b. data/2 -> delay/4 :-)!

Sample

1. 10^6 rows: 800,000 ‘a’, 200,000 ‘b’ or ‘c’
2. Take 10% sample -> 10^5 rows
   a. “What is the ratio of ‘a’ to (‘b’ or ‘c’)?” -> “About 4:1.”
   b. Sampling worked great!
3. 10^1 rows: [a, a, a, c, a, b, a, a, a, a]
   a. Take 10% sample: useless.
4. More information:
   a. ~~Read an article.~~
   b. ~~Read a book.~~
   c. Take a class.

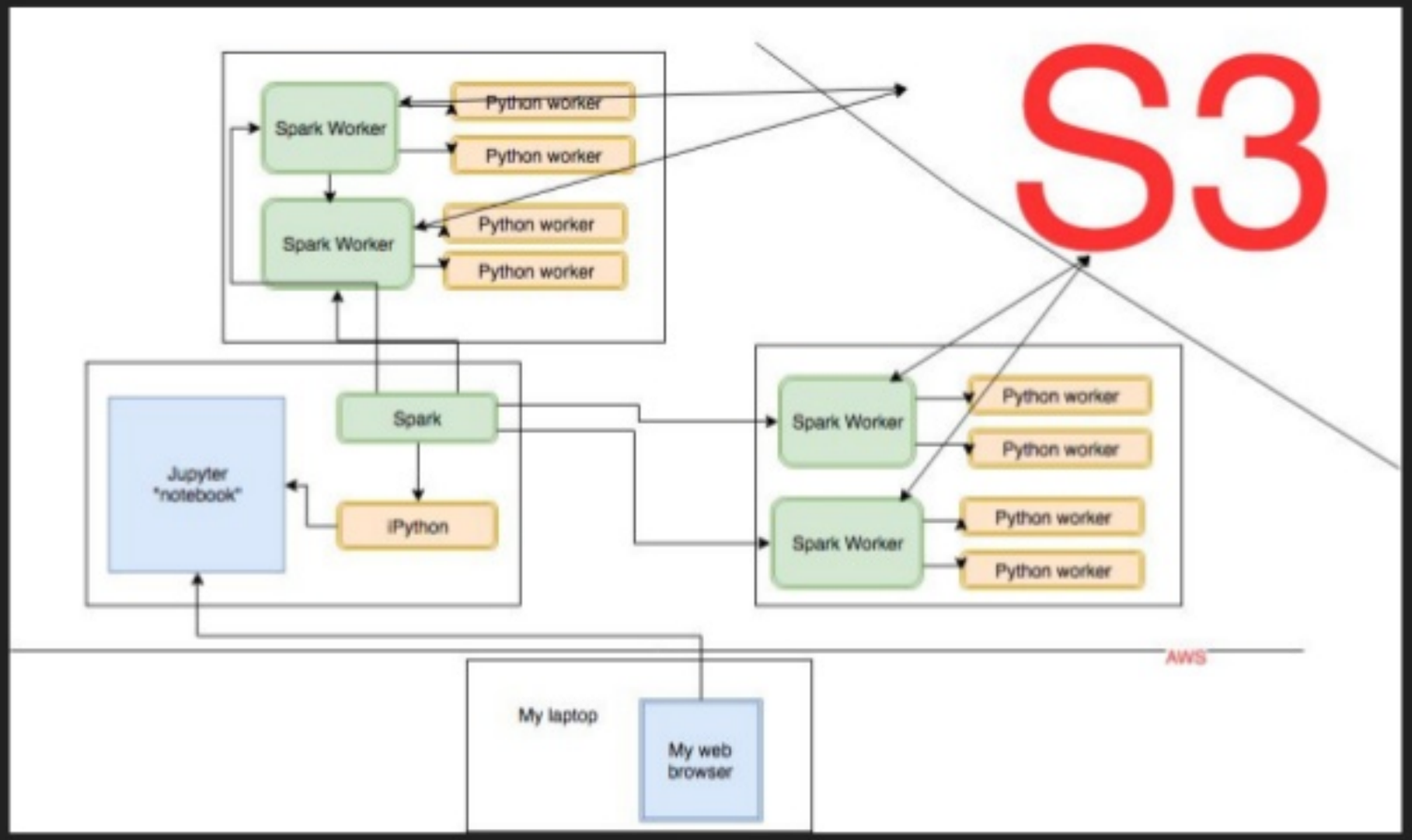
Spend

Toolchain panics: recognition

- **Py4J**NetworkError: An error occurred while trying to connect to the Java server
- **org.apache.spark**.SparkException: Job 330 cancelled; SparkContext was shut down
- **org.apache.spark**.sql.catalyst.errors.package$TreeNodeException
- **org.apache.spark**.SparkException: Kryo serialization failed: Buffer overflow.

Toolchain panics: recovery

- **Lighten** the load
  - Reallocate, sample, ...
- Check toolchain **edges**
  - Spark console, etc.



Synopsis

- Three **symptoms**:
  - Crashes, slowness, unexpected results
- Five **causes**:
  - Variance, cluster state, mental models, exponentiality, heavy load
- One **core technique**:
  - **Localize** the **problem state** to observe it
  - **Scale** out and up in **steps**

In conclusion

A **possibility** you may not have considered ...

Thank you

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