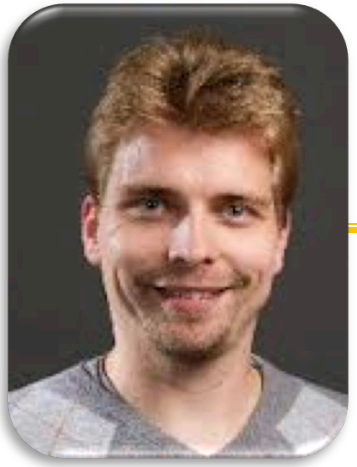

Computational Structures in Data Science

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Lecture #12: Quick: Exceptions and SQL

November 18th, 2016

http://inst.eecs.berkeley.edu/~cs88

Administrivia

- **Open Project: Starts Monday!**
  - **Creative data task**
  - **Similar to data8, except you write the code**
- **Lab Monday: SQL**
- **Lab Monday next week: Talk about Project**

- **Homework: Extra days due to Thanksgiving**

- **Lectures: This one, one more, and Q&A during RRR week**

Computational Concepts Toolbox

- Data type: values, literals, operations,
- Expressions, Call expression
- Variables
- Assignment Statement
- Sequences: tuple, list
- Dictionaries
- Data structures
- Tuple assignment
- Function Definition Statement
- Conditional Statement
- Iteration: list comp, for, while
- Lambda function expr.

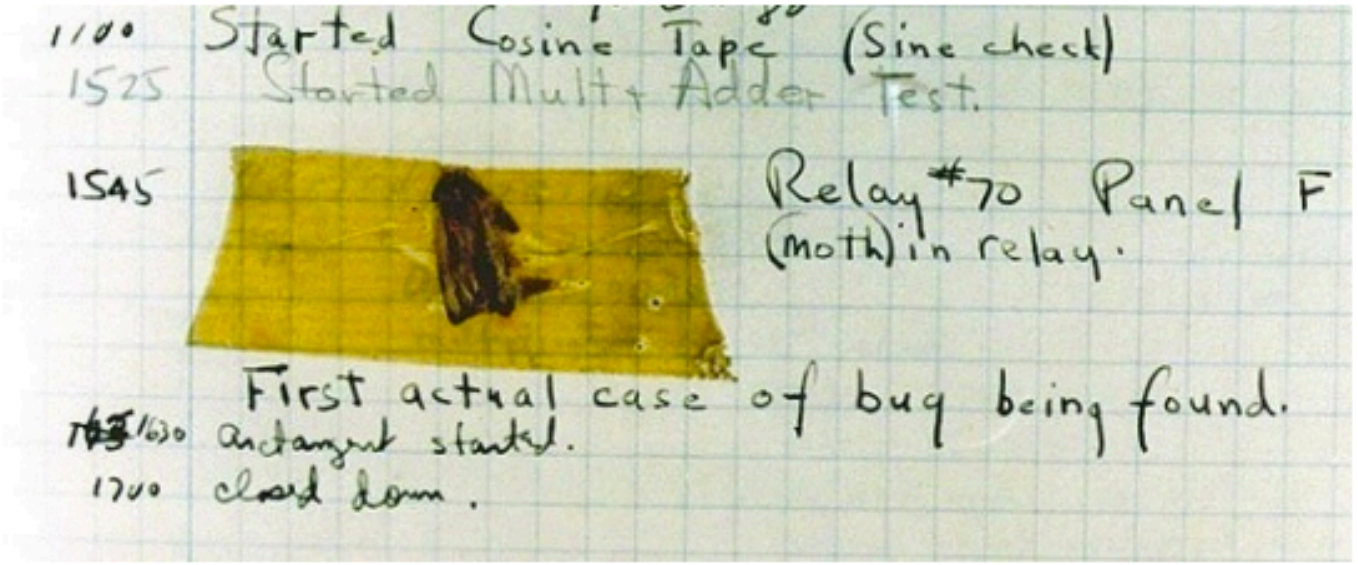
- Higher Order Functions
  - as Values, Args, Results
- Higher order function patterns
  - Map, Filter, Reduce
  - Function factories
- Recursion
  - Linear, Tail, Tree
- Abstract Data Types
- Mutation
- Iterators and Generators
- Object Oriented Programming
- Classes
- Exceptions
- Declarative Programming

Today: Exceptions (read 4.3)

- **Mechanism in a programming language to declare and respond to "exceptional conditions"**
  - **enable non-local continuations of control**
- **Often used to handle error conditions**
  - **Unhandled exceptions will cause python to halt and print a stack trace**
  - **You already saw a non-error exception – end of iterator**
- **Exceptions can be handled by the program instead**
  - **`try, except, raise` statements**
- **Exceptions are objects!**
  - **They have classes with constructors**

Handling Errors

- Function receives arguments of improper type?
- Resource, e.g., file, is not available
- Network connection is lost or times out?



Grace Hopper's Notebook, 1947, Moth found in a Mark II Computer

Example exceptions

```
>>> 3/0
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ZeroDivisionError: division by zero
>>> str.lower(1)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: descriptor 'lower' requires a 'str' object
but received a 'int'
>>> ""[2]
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
IndexError: string index out of range
>>>
```

- **Unhandled, thrown back to the top level interpreter**
- **Or halt the Python program**

Functions

- Q: What is a function supposed to do?
- A: One thing well
- Q: What should it do when it is passed arguments that don't make sense?

```
>>> def divides(x, y):
...     return y%x == 0
...
>>> divides(0, 5)
???

>>> def get(data, selector):
...     return data[selector]
...
>>> get({'a': 34, 'cat':'9 lives'}, 'dog')

????
```

Exceptional exit from functions

```
>>> def divides(x, y):
...     return y%x == 0
...
>>> divides(0, 5)
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 2, in divides
ZeroDivisionError: integer division or modulo by zero
>>> def get(data, selector):
...     return data[selector]
...
>>> get({'a': 34, 'cat':'9 lives'}, 'dog')
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
  File "<stdin>", line 2, in get
KeyError: 'dog'
>>>
```

- **Function doesn't "return" but instead execution is thrown out of the function**

Continue out of multiple calls deep

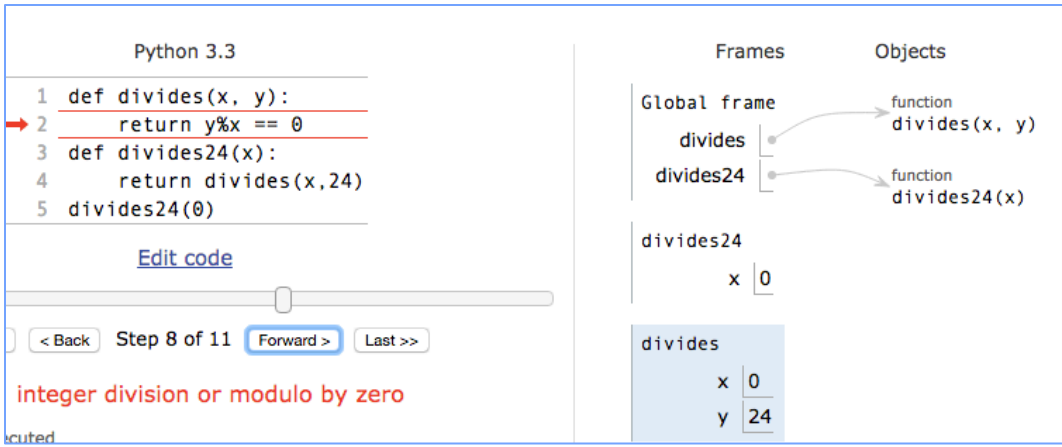
```
def divides(x, y):
    return y%x == 0
def divides24(x):
    return divides(x,24)
divides24(0)
```

```
---------------------------------------------------------------------------
ZeroDivisionError                         Traceback (most recent call last)
<ipython-input-14-ad26ce8ae76a> in <module>()
      3 def divides24(x):
      4     return divides(x,24)
----> 5 divides24(0)

<ipython-input-14-ad26ce8ae76a> in divides24(x)
      2     return y%x == 0
      3 def divides24(x):
----> 4     return divides(x,24)
      5 divides24(0)

<ipython-input-14-ad26ce8ae76a> in divides(x, y)
      1 def divides(x, y):
----> 2     return y%x == 0
      3 def divides24(x):
      4     return divides(x,24)
      5 divides24(0)

ZeroDivisionError: integer division or modulo by zero
```



- **Recursion/Stack unwinds until exception is handled or top**

Types of exceptions

- `TypeError` -- A function was passed the wrong number/type of argument
- `NameError` -- A name wasn't found
- `KeyError` -- A key wasn't found in a dictionary
- `RuntimeError` -- Catch-all for troubles during interpretation
- `...`

Flow of control stops at the exception

- And is 'thrown back' to wherever it is caught

```
def divides24(x):
    return noisy_divides(x,24)
```

```
divides24(0)
```

```
---------------------------------------------------------------------
ZeroDivisionError                         Traceback (most recer
<ipython-input-24-ea94e81be222> in <module>()
----> 1 divides24(0)

<ipython-input-23-c56bc11b3032> in divides24(x)
      1 def divides24(x):
----> 2     return noisy_divides(x,24)

<ipython-input-20-df96adb0c18a> in noisy_divides(x, y)
      1 def noisy_divides(x, y):
----> 2     result = (y % x == 0)
      3     if result:
      4         print("{0} divides {1}".format(x, y))
      5     else:

ZeroDivisionError: integer division or modulo by zero
```

Assert Statements

- **Allow you to make assertions about assumptions that your code relies on**
  - **Use them liberally!**
  - **Incoming data is dirty till you've washed it**

```
assert <assertion expression>, <string for failed>
```

- **Raise an exception of type `AssertionError`**
- **Ignored in optimize flag: python3 –O …**
  - **Governed by bool `__debug__`**

```
def divides(x, y):
    assert x != 0, "Denominator must be non-zero"
    return y%x == 0
```

Handling Errors – `try` / `except`

- **Wrap your code in `try` — `except` statements**

```
try:
    <try suite>
except <exception class> as <name>:
    <except suite>
... # continue here if <try suite> succeeds w/o exception
```

- **Execution rule**
  - **<try suite> is executed first**
  - **If during this an exception is raised and not handled otherwise**
  - **And if the exception inherits from <exception class>**
  - **Then <except suite> is executed with <name> bound to the exception**
- **Control jumps to the except suite of the most recent `try` that handles the exception**

Raise statement

- Exception are raised with a `raise` statement

```
raise <exception>
```

- <expression> must evaluate to a subclass of BaseException or an instance of one
- Exceptions are constructed like any other object

```
TypeError('Bad argument')
```

Exceptions are Classes

```
class NoiseyException(Exception):
    def __init__(self, stuff):
        print("Bad stuff happened", stuff)
```

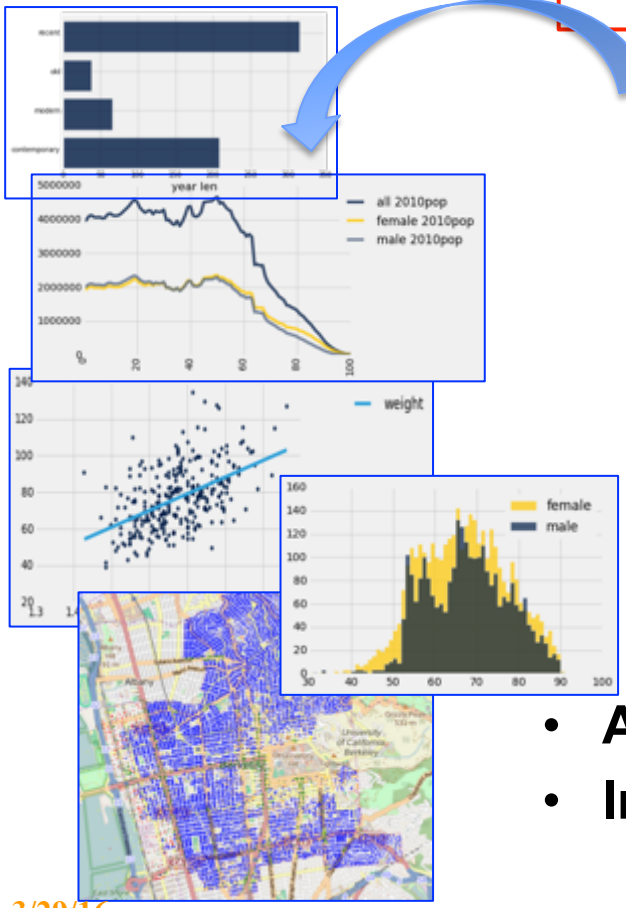
```
try:
    return fun(x)
except:
    raise NoiseyException((fun, x))
```

Part II – Intro to Declarative Programming SQL

Data 8 Tables

ordered collection of labeled columns of anything

dict, record,tuple



label

values

select, where, take, drop, group
stats, bin
sample
pivot,
pivot_bin

split

join

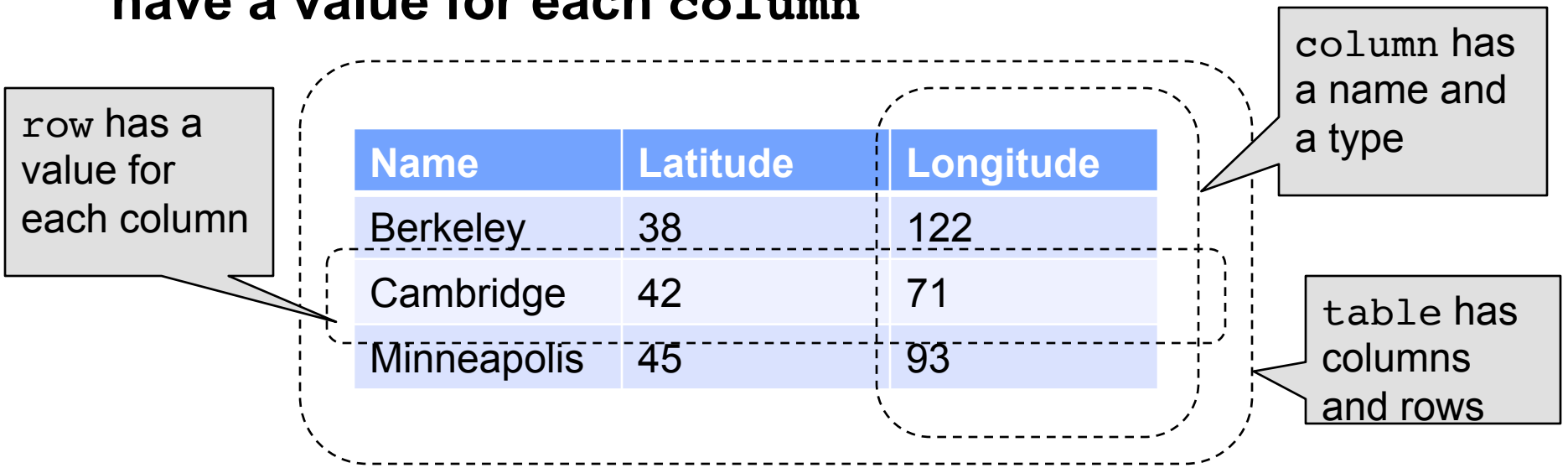
T['label']

Numpy array

- **A single, simple, powerful data structure for all**
- **Inspired by Excel, SQL, R, Pandas, Numpy, …**

Database Management Systems

- **DBMS are persistent tables with powerful relational operators**
  - **Important, heavily used, interesting !**
- **A `table` is a collection of `records`, which are `rows` that have a value for each `column`**



Name	Latitude	Longitude
Berkeley	38	122
Cambridge	42	71
Minneapolis	45	93

- **Structure Query Language (SQL) is a declarative programming language describing operations on tables**

SQL

- A declarative language
  - Described *what* to compute
  - Imperative languages, like python, describe *how* to compute it
  - Query processor (interpreter) chooses which of many equivalent query plans to execute to perform the SQL statements
- ANSI and ISO standard, but many variants
- `select` statement creates a new table, either from scratch or by projecting a table
- `create table` statement gives a global name to a table
- Lots of other statements
  - `analyze, delete, explain, insert, replace, update, …`
- The action is in select

SQL example

- **SQL statements create tables**
  - **Give it a try with sqlite3 or http://kripken.github.io/sql.js/GUI/**
  - **Each statement ends with ';'**

```
culler$ sqlite3
SQLite version 3.9.2 2015-11-02 18:31:45
Enter ".help" for usage hints.
Connected to a transient in-memory database.
Use ".open FILENAME" to reopen on a persistent database.
sqlite> select 38 as latitude, 122 as longitude, "Berkeley" as
name;
38|122|Berkeley
sqlite>
```

select

- **Comma-separated list of *column descriptions***
- **Column description is an expression, optionally followed by `as` and a column name**

```
select [expression] as [name], [expression] as [name]; . . .
```

- **Selecting literals creates a one-row table**
- **`union` of select statements is a table containing the union of the rows**

```
select 38 as latitude, 122 as longitude, "Berkeley" as name union
select 42,             71,               "Cambridge" union
select 45,             93,               "Minneapolis";
```

Latitude	Longitude	Name
38	122	Berkeley
42	71	Cambridge
45	93	Minneapolis

SQL: creating a named table

```
create table cities as
 select 38 as latitude, 122 as longitude, "Berkeley" as name union
 select 42,             71,               "Cambridge" union
 select 45,             93,               "Minneapolis";
```

cities:

Latitude	Longitude	Name
38	122	Berkeley
42	71	Cambridge
45	93	Minneapolis

`create table`

- **SQL often used interactively**
  - **Result of select displayed to the user, but not stored**
- **Create table statement gives the result a name**
  - **Like a variable, but for a permanent object**

```
create table [name] as [select statement];
```

SQL: using named tables - `from`

```
create table cities as
 select 38 as latitude, 122 as longitude, "Berkeley" as name union
 select 42,             71,               "Cambridge" union
 select 45,             93,               "Minneapolis";

select "west coast" as region, name from cities where longitude
>= 115 union
select "other", name from cities where longitude < 115
```

cities:

Latitude	Longitude	Name
38	122	Berkeley
42	71	Cambridge
45	93	Minneapolis

Region	Name
west coast	Berkeley
other	Cambridge
other	Minneapolis

Projecting existing tables

- Input table specified by `from` clause
- Subset of rows selected using a `where` clause
- Ordering of the selected rows declared using an `order by` clause

`select` [columns] `from` [table] `where` [condition] `order by` [order] ;

```
select * from cities where longitude > 115 order by name;
```

Name	Latitude	Longitude
Cambridge	42	71
Minneapolis	45	93

Joining tables

- **Two tables are joined by a comma to yield all combinations of a row from each**

```
create table cities as
 select 38 as latitude, 122 as longitude, "Berkeley" as name union
 select 42,             71,               "Cambridge" union
 select 45,             93,               "Minneapolis";

create table climates as
 select "Berkeley" as city, "warm" as climate union
 select "Cambridge" as city, "cold" as climate;

select * from cities, climates
```

latitude	longitude	name	city	climate
38	122	Berkeley	Berkeley	warm
38	122	Berkeley	Cambridge	cold
42	71	Cambridge	Berkeley	warm
42	71	Cambridge	Cambridge	cold
45	93	Minneapolis	Berkeley	warm
45	93	Minneapolis	Cambridge	cold

Join / Where

```
create table cities as
 select 38 as latitude, 122 as longitude, "Berkeley" as name union
 select 42,             71,               "Cambridge" union
 select 45,             93,               "Minneapolis";

create table climates as
 select "Berkeley" as city, "warm" as climate union
 select "Cambridge" as city, "cold" as climate;

select name, climate, latitude, longitude from cities, climates
where name = city;
```

name	climate	latitude	longitude
Berkeley	warm	38	122
Cambridge	cold	42	71

Aggregation and grouping

- **Reduction operators can be applied over groupings of rows**

```
create table cities as
 select 38 as latitude, 122 as longitude, "Berkeley" as name union
 select 42,             71,               "Cambridge" union
 select 45,             93,               "Minneapolis";

create table climates as
 select "Berkeley" as city, "warm" as climate union
 select "Cambridge" as city, "cold" as climate union
 select "Minneapolis" as city, "cold" as climate;

select climate, min(latitude) from cities, climates where name =
city group by climate;
```

climate	min(latitude)
cold	42
warm	38

Summary

- Exceptions provide a way to handle unexpected cases and errors
- Transfers control to enclosing handler of matching type
  - assert, raise <expression> , try: … except <type> as <name>
- SQL a declarative programming language on relational tables
  - largely familiar to you from data8
  - create, select, where, order, group by, join
- More in lab!