hail Tables

https://hail.is/docs/0.2/hail.Table.html

Laziness and Actions – Understanding hail's computational model

For performance reasons, most hail methods are **lazy.** Calling a lazy method does not immediately begin a computation. Instead, it creates a python object representing that computation, which we call an **Expression**. Because of this, many standard python methods won't work on hail expressions.

Python	Hail
`3 if x>0 else 2`	`hl.cond(x>0,3,2)`
`len(arr)`	`hl.len(arr)`
`"foo" in a`	`a.contains("foo")`

Expressions only get evaluated when an **action** is performed. Actions are functions which force hail to compute a result, either by printing some information, returning a local python value, or writing to a file.

Some examples of actions:

```
ht.show()
ht.write(path)
ht.take(k)
ht.collect()
ht.aggregate(...)
```

Creating Tables

```
ht = hl.read_table('path/table.ht')
```
Read in a hail formatted table file.

```
ht = hl.import_table('path/dat.csv',
                  delimiter=',')
```
Read in data from a CSV.

```
ht = hl.Table.from_pandas(df)
```
Create a Table from pandas dataframe.

```
ht = hl.utils.range_table(10)
```
Create a Table with 10 rows and one field, **idx**.

```
ht = hl.Table.parallelize(
 hl.literal(
  [{"a": 4, "b": 7, "c": 10},
   {"a": 5, "b": 8, "c": 11},
   {"a": 6, "b": 9, "c": 12}],
'array<struct{a:int,b:int,c:int}>'))
```
Create a hail table by specifying each row.

Exporting Tables

```
ht.write('path/file.ht')
```
Write out the table as hail formatted **ht** file

```
ht.export('path/file.csv', delimiter=',')
```
Write out table to a csv.

```
df = ht.to_pandas()
```
Make a local hail dataframe from the table

```
df = ht.to_spark()
```
Make a distributed spark dataframe from the table

Globals

Globals are extra table fields that are identical for every row, but are only stored once for efficiency. Globals can be used in hail expressions just like row fields.

```
ht.annotate_globals(source="broad")
```
Add a global field called "source" equal to "broad"

ht.globals.show()
Show the global fields for this table.

Exploring Tables

```
ht.describe()
```
Print information about the types of each field

```
ht.summarize()
```
Basic descriptive statistics for each field

```
ht.count()
```
# of rows in table

```
ht.show(n)
```
Print first n rows of table (forces computation!)

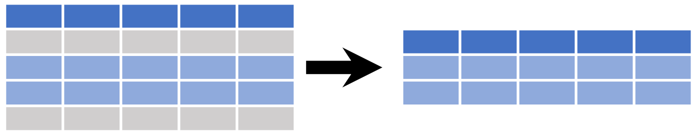
```
ht.n_partitions()
```
Check how many partitions your table has.

Adding Keys

```
ht.key_by("year")
```
Keys the table by the "year" field.

```
ht.key_by()
```
Key by with no elements unkeys the table.

Subset Observations (Rows)



```
ht.filter(ht.length > 7)
```
Keep rows that meet criteria.

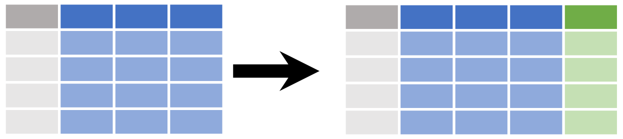
```
ht.distinct()
```
Remove rows with duplicate keys

```
ht.sample(.05)
```
Randomly select fraction of rows.

```
ht.head(n)
```
Subset table to first n rows

```
ht.tail(n)
```
Subset table to last n rows

Add New Fields

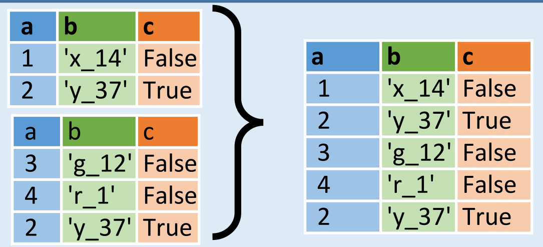


```
ht.annotate(area= ht.length*ht.width)
```
Compute and append one or more new fields to each row.

```
ht.transmute(area= ht.length*ht.width)
```
Like annotate, but deletes referenced fields (length and width above)

ht.add_index()
Add a column called "idx" to table that numbers each row in order.

Reshaping Data – Change the layout of a data set

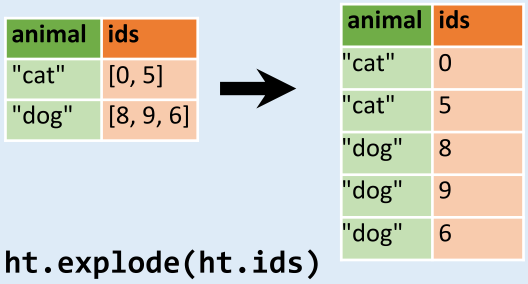


a	b	c
1	'x_14'	False
2	'y_37'	True

a	b	c
3	'g_12'	False
4	'r_1'	False
2	'y_37'	True

a	b	c
1	'x_14'	False
2	'y_37'	True
3	'g_12'	False
4	'r_1'	False
2	'y_37'	True

```
ht1.union(ht2, ht3, ...)
```
Append rows of multiple tables



animal	ids
"cat"	[0, 5]
"dog"	[8, 9, 6]

animal	ids
"cat"	0
"cat"	5
"dog"	8
"dog"	9
"dog"	6

```
ht.explode(ht.ids)
```
Create one row for each entry in array field

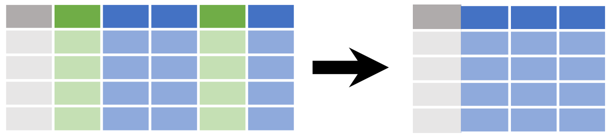
```
ht.order_by('mpg')
```
Order rows by values of 'mpg' field (low to high).

```
ht.order_by(hl.dsc('mpg'))
```
Order rows by values of 'mpg' field (low to high).

```
ht.rename({'y':'year'})
```
Rename the fields of a Table

```
ht.drop('length','height')
```
Drop fields from the table

Subset Variables (Fields)



```
ht.select('a', 'b')
```
Select several fields by name

`ht['a']` *or* **ht.a**
Select single field with specific name

```
ht.select(*(x for x in ht.row if re.match(pattern, x))
```
Select fields whose name matches regular expression \`pattern\`

```
ht.drop(*(x for x in ht.row if re.match(pattern, x))
```
Drop fields whose name matches regular expression \`pattern\`

regex (Regular Expressions) Examples	
`'\.'`	Matches strings containing a period '.'
`'Length$'`	Matches strings ending with word 'Length'
`'^Sepal'`	Matches strings beginning with the word 'Sepal'
`'^x[1-5]$'`	Matches strings 'x1', 'x2', 'x3', 'x4', 'x5'.
`'^(?!Species$).*'`	Matches strings except the string 'Species'

http://hail.is This cheat sheet inspired by Rstudio Data Wrangling Cheatsheet (https://www.rstudio.com/wp-content/uploads/2015/02/data-wrangling-cheatsheet.pdf) and pandas (https://pandas.pydata.org/Pandas_Cheat_Sheet.pdf)

Aggregations

```
ht.aggregate(hl.agg.counter(ht.b))
```

Count number of rows with each unique value for field **a**

id	a	b
4	3.4	"cat"
7	5.7	"dog"
9	-0.9	"cat"

→ {"cat":2, "dog":1}

Besides the above, hail provides a large set of **aggregation functions** that operate on fields of the hail table. They are found in the `hl.agg` module. You can call these functions using `ht.aggregate`.

`hl.agg.sum(ht.a)`
Sum values of field **a**.

`hl.agg.approx_median(ht.a)`
Median value of field **a**.

```
hl.agg.approx_quantiles(
  ht.a, [.2, .7, .9])
```
Approximate quantiles of field **a**.

`hl.agg.std(ht.a)`
Standard deviation of field **a**.

`hl.agg.min(ht.a)`
Minimum value of field **a**.

`hl.agg.max(ht.a)`
Maximum value of field **a**.

`hl.agg.mean(ht.a)`
Mean value of field **a**.

`hl.agg.var(ht.a)`
Variance of field **a**.

Group Data

```
ht.group_by("col")
```
Return a GroupedTable object, grouped by values in column named "col".

```
ht.group_by(level=ht.col % 10)
```
Return a GroupedTable object that is grouped based on the newly computed value `level`

Any call to `group_by` should always be followed by a call to `aggregate` to get back a Table. See aggregation functions above.

Scans

idx	num
0	7
1	3
2	5
3	11

→

idx	num	sum	prod	max
0	7	0	1	NA
1	3	7	7	7
2	5	10	21	7
3	11	15	105	7

```
ht.annotate(sum =  hl.scan.sum(ht.num),
            prod = hl.scan.product(ht.num),
            max =  hl.scan.max(ht.num))
```

Scans allow rolling aggregations along rows of a table. Each aggregator function has a corresponding scan function.

Handling Missing Data

```
ht.annotate(x=hl.coalesce(ht.x, val))
```
Create a new table where missing values in **x** are replaced by val

```
ht.filter(hl.is_defined(ht.x))
```
Create a new table where rows with a missing value for **x** are removed.

Combine Data Sets

ht1

x1	x2
A	1
B	2
C	3

+

ht2

x1	x3
A	T
B	F
B	T
D	T

=

Standard Joins (**x1 is the key for both tables**)

x1	x2	x3
A	1	T
B	2	F
B	2	T
C	3	NA

```
ht1.join(ht2, how='left')
```
Join matching rows from ht2 to ht1.

x1	x2	x3
A	1	T
B	2	F
B	2	T
D	NA	T

```
ht1.join(ht2, how='right')
```
Join matching rows from ht1 to ht2.

x1	x2	x3
A	1	T
B	2	F
B	2	T

```
ht1.join(ht2, how='inner')
```
Join data. Retain only rows in both sets.

x1	x2	x3
A	1	T
B	2	F
B	2	T
C	3	NA
D	NA	T

```
ht1.join(ht2, how='outer')
```
Join data. Retain all values, all rows.

Mapping Join Syntax

x1	x2	x3
A	1	T
B	2	F
C	3	NA

```
ht1.annotate(**ht2[ht1.x1])
```
Join matching rows from ht2 to ht1, does not keep duplicates.

Filtering Joins

x1	x2
A	1
B	2

```
ht1.semi_join(ht2)
```
Keep rows whose keys appear in both ht1 and ht2

x1	x2
C	3

```
ht1.anti_join(ht2)
```
Keep rows whose keys appear in ht1 but not ht2

Plotting

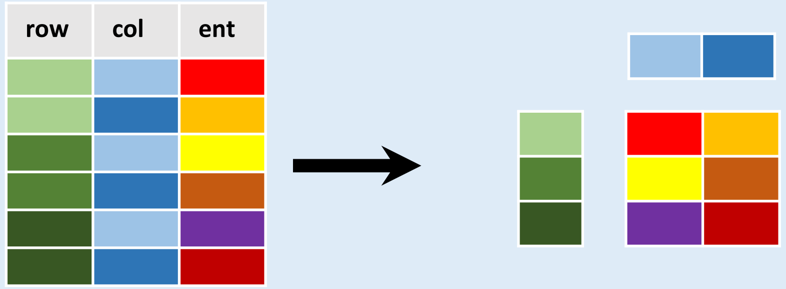
Hail plotting functions return a figure which can be shown with `hl.plot.show(fig)`

`hl.plot.histogram(ht.y)`
Histogram of values of field y

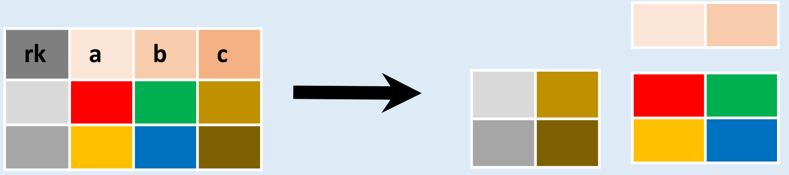
`hl.plot.scatter(ht.x, ht.y)`
Scatter chart using pairs of points

Interacting with MatrixTable

From Table to MatrixTable



```
mt = ht.to_matrix_table(row_key=['row'], col_key=['col'])
```
Convert a Table in coordinate representation to a MatrixTable



```
mt = ht.to_matrix_table_row_major(columns=['a', 'b'],
        entry_field_name='ent', col_field_name='col')
```
Convert a Table in row-major representation to a MatrixTable

From MatrixTable to Table

`mt.rows()`
Returns a table with all row fields in the MatrixTable.

`mt.cols()`
Returns a table with all col fields in the matrix.

`mt.entries()`
Converts the matrix to a table in coordinate form.

`mt.globals_table()`
Returns a table with a single row containing the globals.

Useful Hail Functions	
`hl.literal(py_obj)`	Turn a python object into equivalent hail expression.
`hl.if_else(pred, consequent, alternate)`	If **pred** is true, return consequent, else return alternate.
`hl.sorted(a)`	Sorts array **a**

`hl.argmin(a)`
`hl.argmax(a)`
	Index of min/max element in **a**

`hl.min(a)/hl.max(a)`	Min/max element in **a**
`hl.coalesce(*args)`	Return first nonmissing value of args.
`a.contains("foo")`	Check if array **a** contains "foo"
`hl.is_missing(expr)`	Check if an expr is missing
`hl.is_nan(expr)`	Check if an expr is NaN
`&,|,~,^`	Logical and/or/not/xor