

# Hybrid Scripting/Vis Tool Development in Jupyter Notebooks

Leveraging human centric methods for performance analysis workflows

Scalable Tools - June 19, 2023

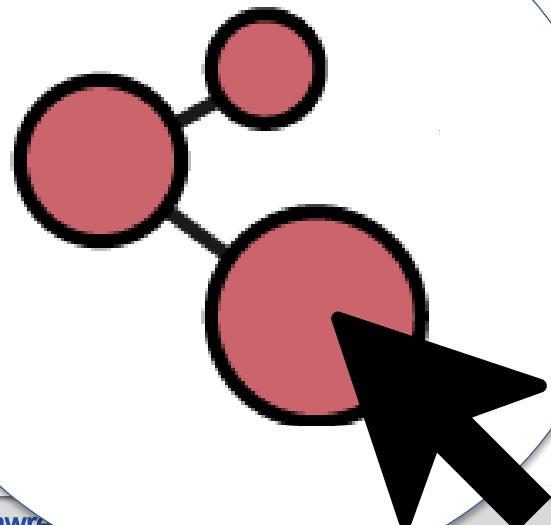
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# A Tale of Two Workflows

Script based tools for:

- Measuring Code/Generating Data
- Cleaning/Formatting Datasets
- Calculating Derived Metrics

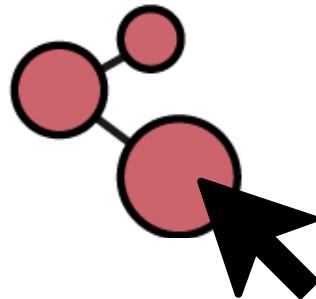
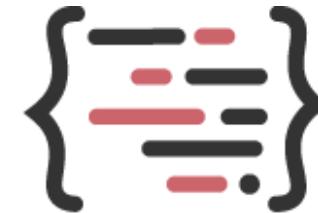


GUI-Based tools and visualizations for:

- Analyzing Metrics
- Communicating Work Done
- Identifying Bottlenecks

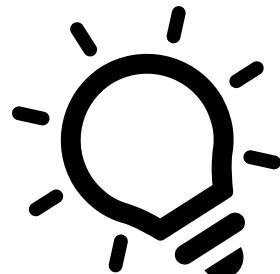
# Filling the Gap

Scripting can support a vast range of expressions and functionalities but can be cumbersome for analysis.



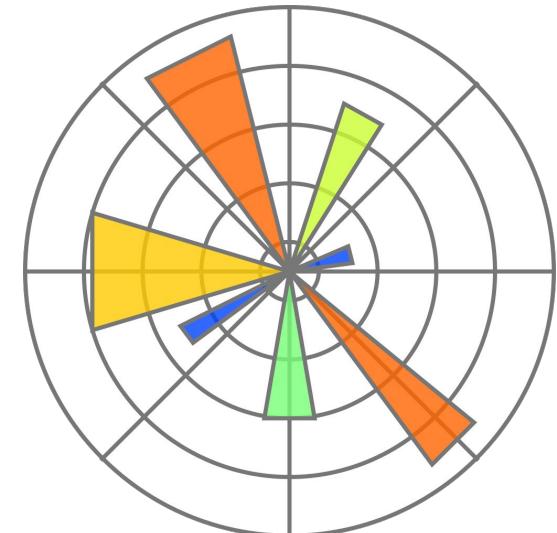
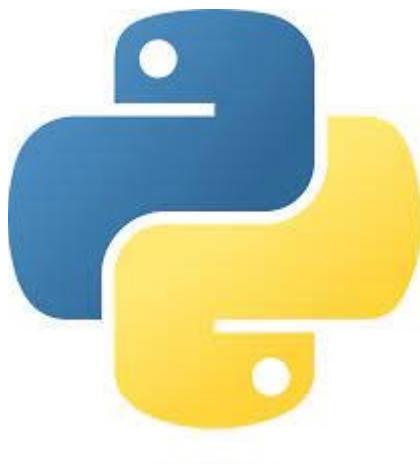
Interactive Visualization can support fluid exploration but is often limited to pre-determined tasks

**So how do we reconcile these two needs for performance analysts and tie these workflows together?**

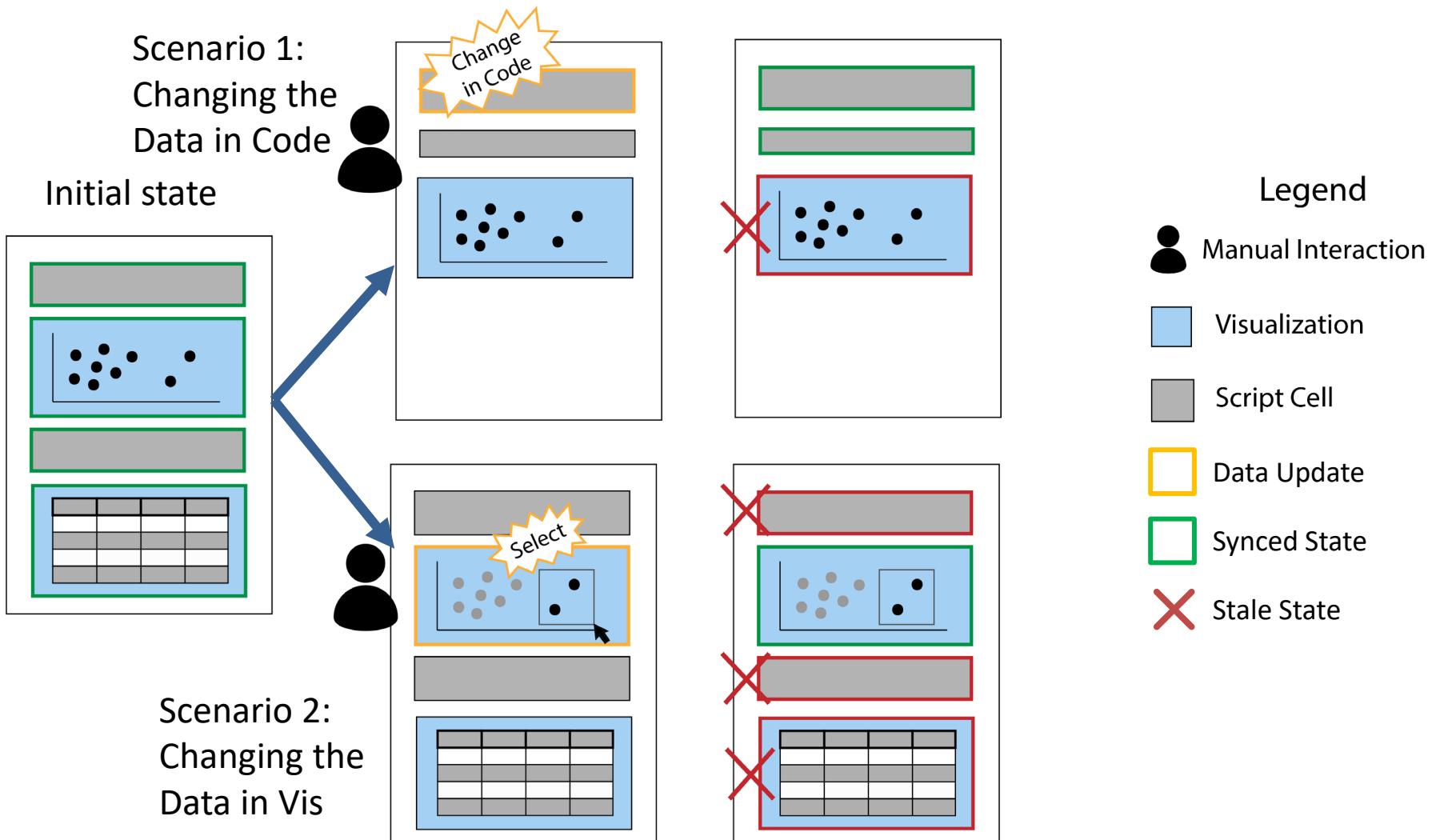


We develop tools embedded in Jupyter notebooks that leverage both **visualization** and scripting to give the users flexibility they seek.

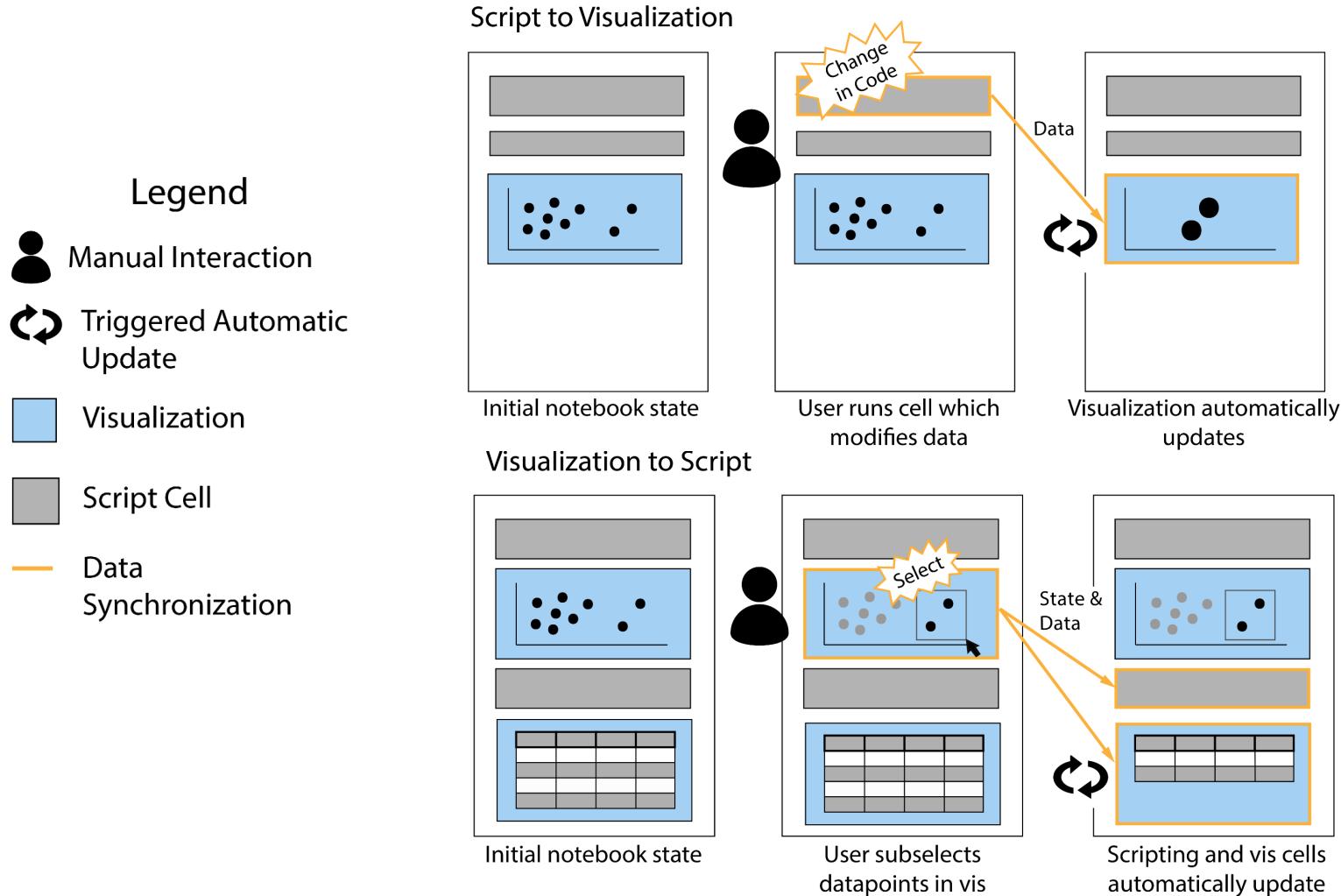
# Do Jupyter Notebooks alone fill this gap?



# Where Notebooks Fail to Support Hybrid Workflows



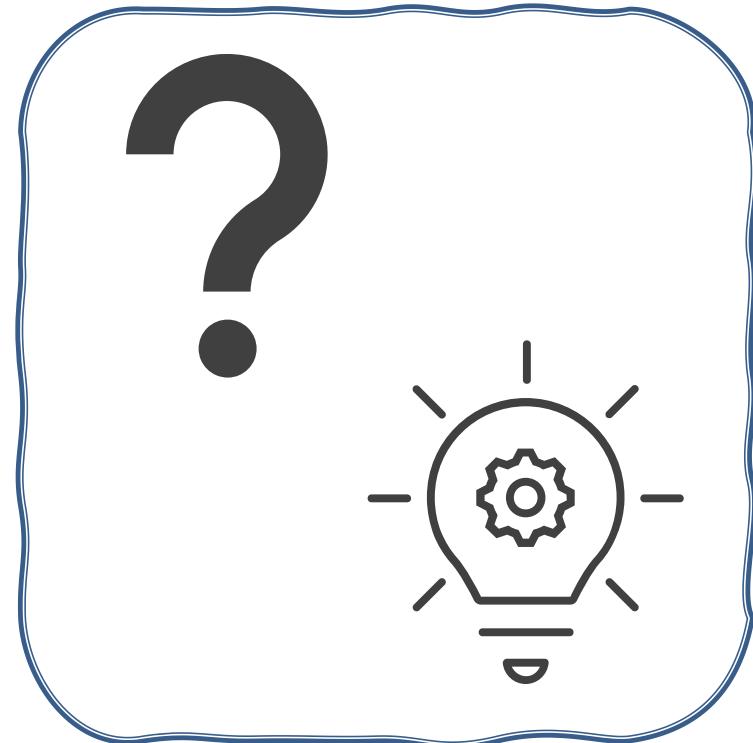
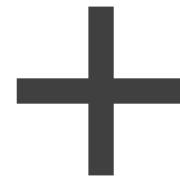
# What is the better model for a hybrid workflow?



# The Equation of Good Hybrid Design



Technology for Implementation

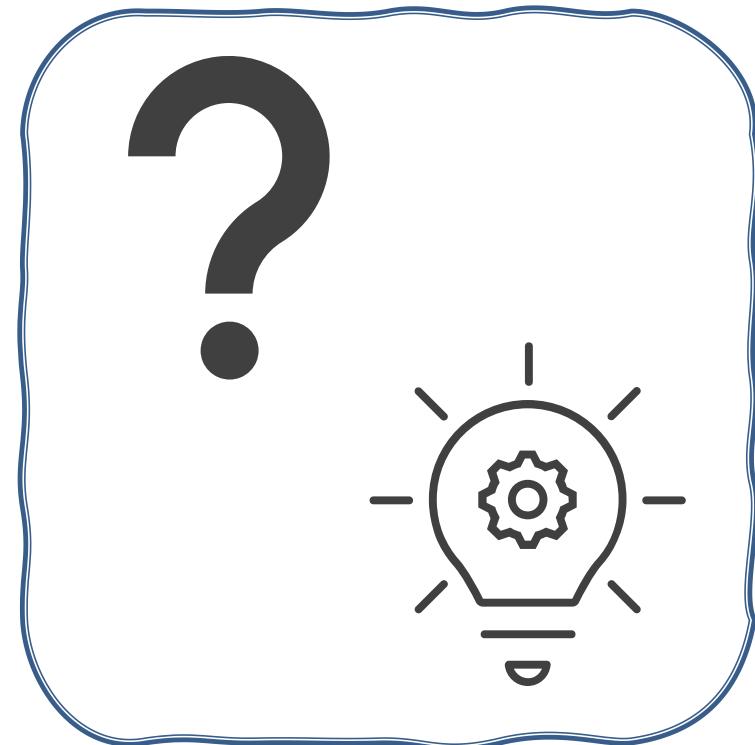
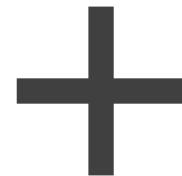


Model of Design

# The Equation of Good Hybrid Design

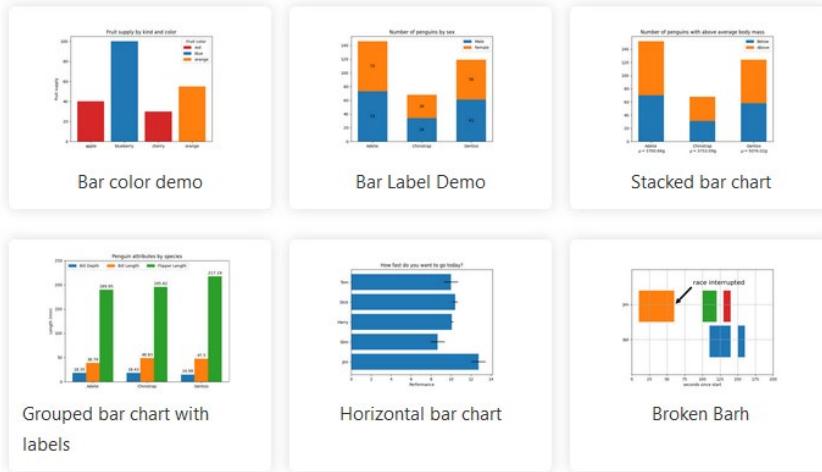


Technology for Implementation



Model of Design

# Python Vis alone is not enough

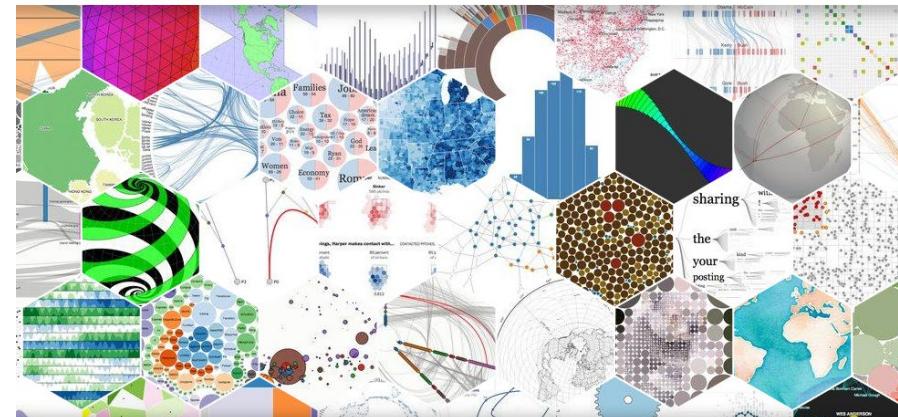


## Python for Visualizations

- VIS libraries are not flexible enough for fully custom visualizations
  - (I.E. Matplotlib, Bokeh)
- Use GUI rendering tools with various object/view models
- Low level syntax makes mapping data to visual elements difficult



Data-Driven Documents



# Libraries for Loading Javascript in Notebooks

## Notebook JS

Library for loading JavaScript from individual notebook cells

**Pro:** Transparent syntax for notebook user

**Con:** No longer being supported/developed

## Roundtrip

Provides interfaces for managing data/state between notebook and JS vis.

**Pro:** Supports complex data and state tracking

**Con:** Unoptimized research code

## Jupyter Widgets and Traitlets

Libraries which work together to load vis and manage data transfer between JS and Jupyter.

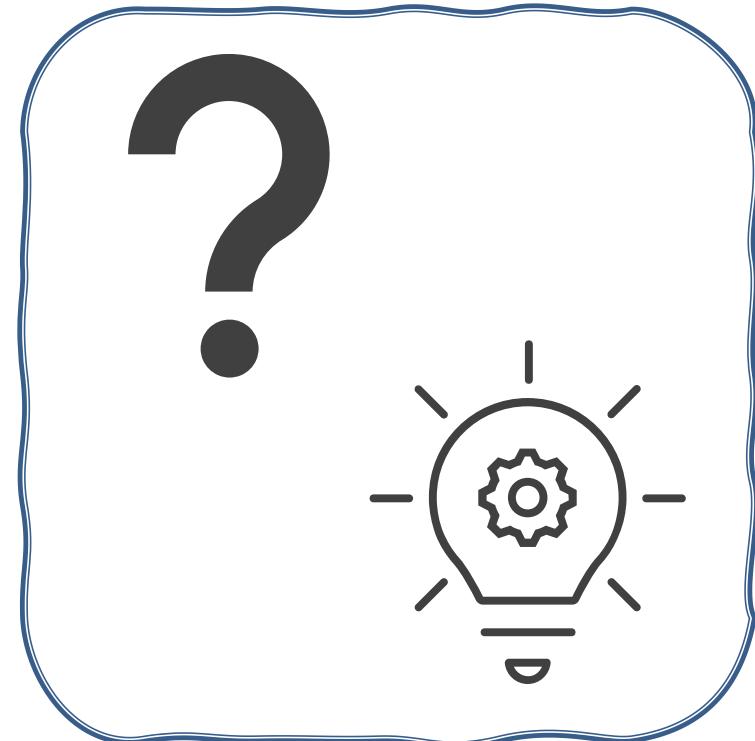
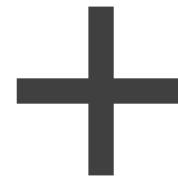
**Pro:** Intuitive object-oriented syntax

**Con:** Tight integration between JS and Python code

# The Equation of Good Hybrid Design



Technology for Implementation



Model of Design

# The Equation of Good Hybrid Design



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Roundtrip

Model of Design

# Example Tasks – Performance Analysis

## Tasks

Calculate Speedup (CPU/GPU)

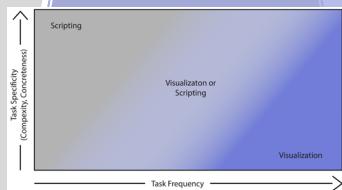
Run Nightly Tests

Find Optimization Opportunities

Report on Work Done

# Tasks Naturally Suited to Scripting

# Tasks Naturally Suited to Visualization



# Task Categorization

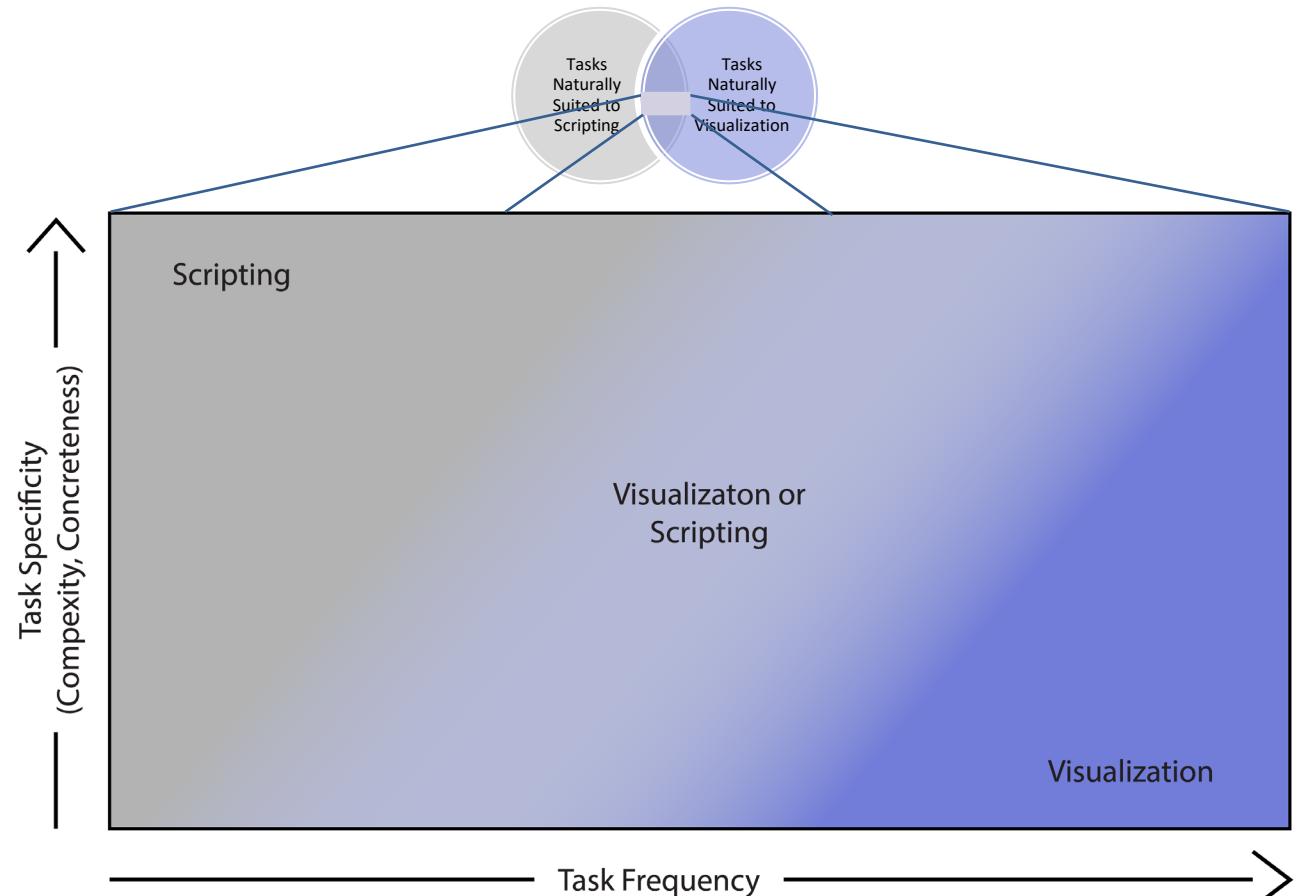
## Tasks

Calculate Speedup  
(CPU/GPU)

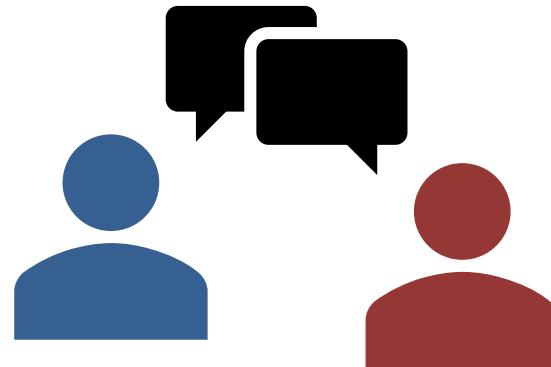
Find Optimization  
Opportunities

Run Nightly Tests

Report on Work  
Done



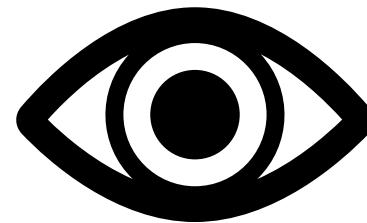
# HCI 101 – Understanding Your User’s Tasks



Interviewing/Discussions

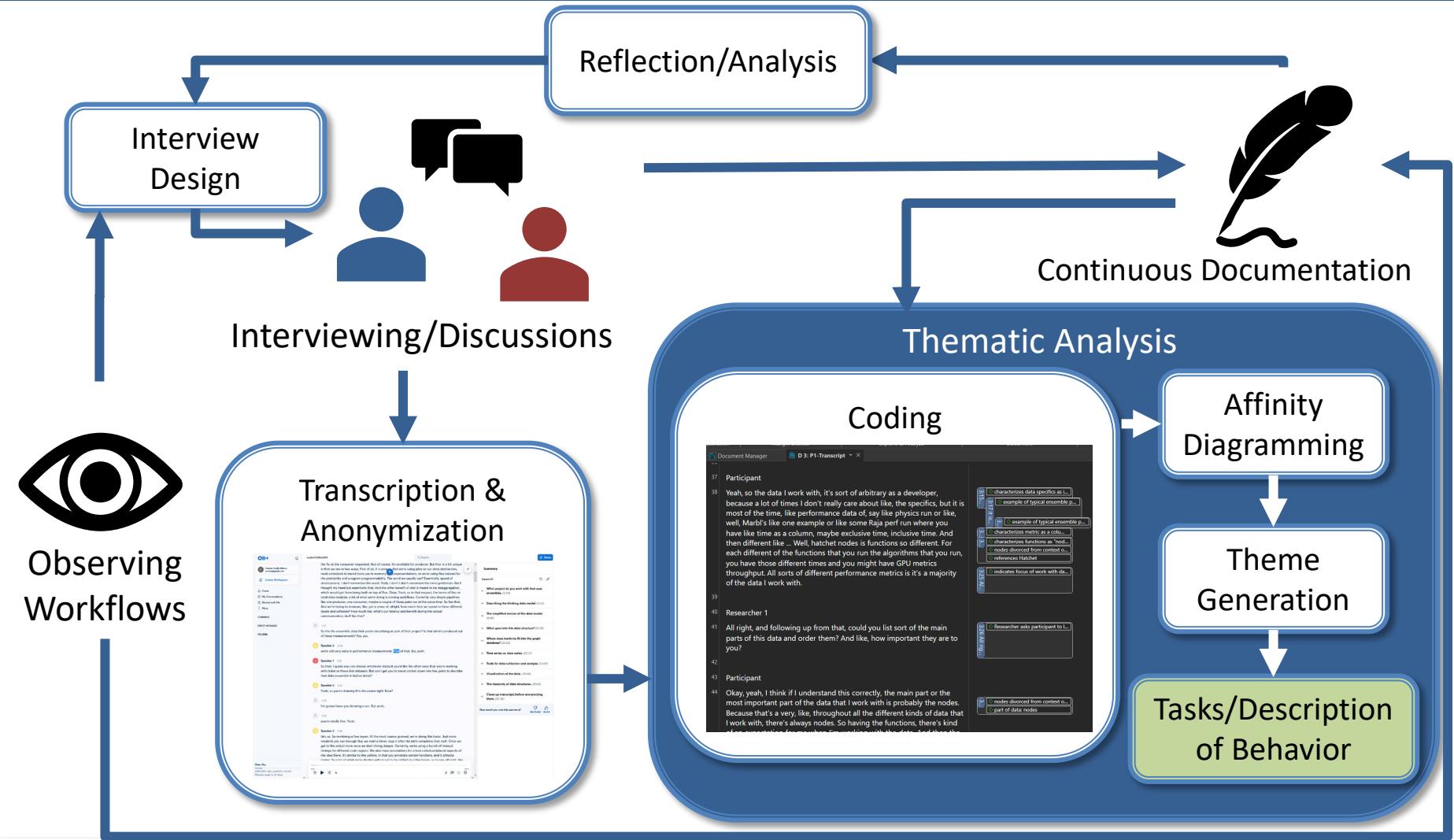


Continuous Documentation



Observing Workflows

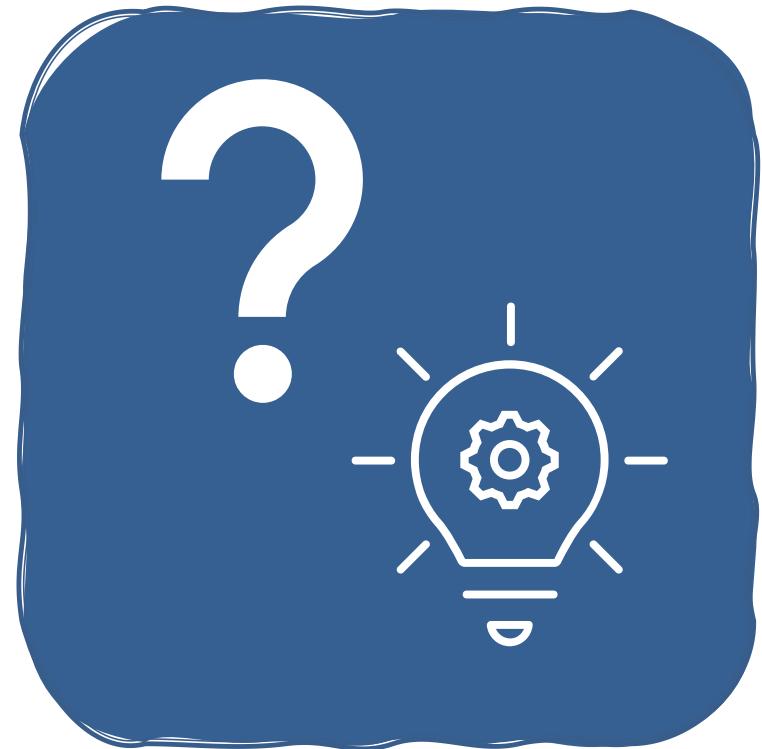
# HCI 601 – What This Actually Entails . . .



# The Equation of Good Hybrid Design



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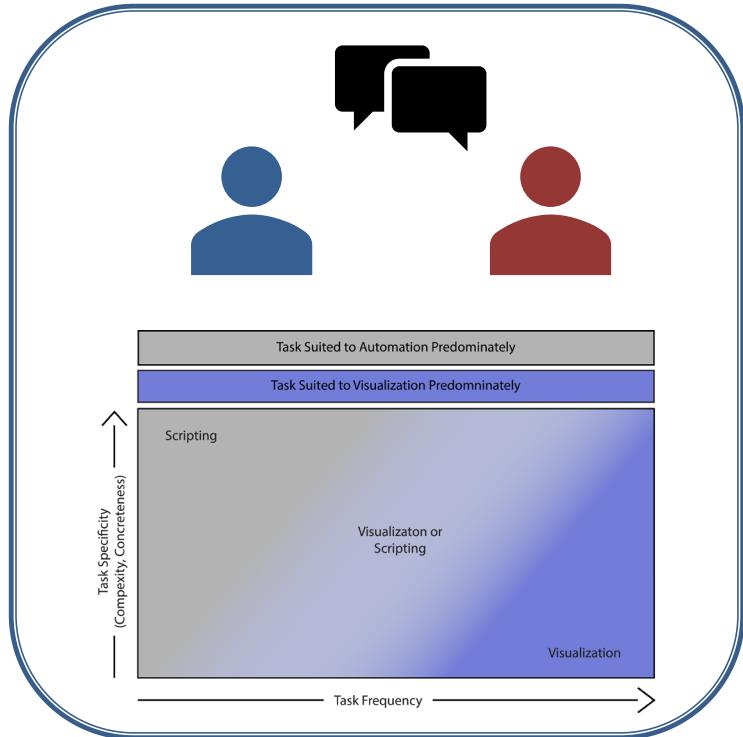
Roundtrip

Model of Design

# The Equation of Good Hybrid Design



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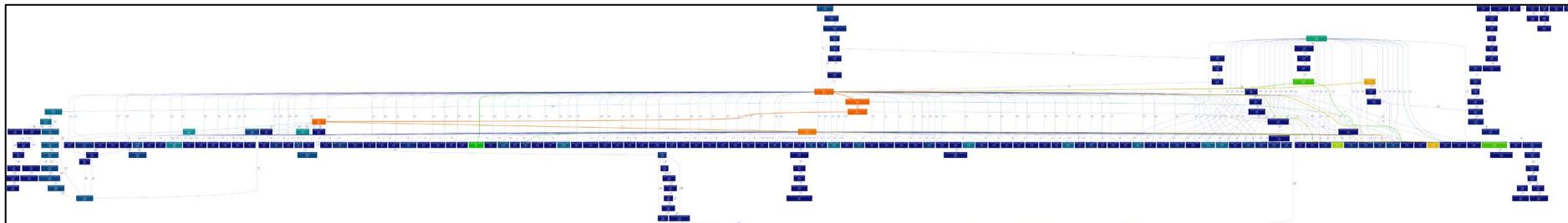
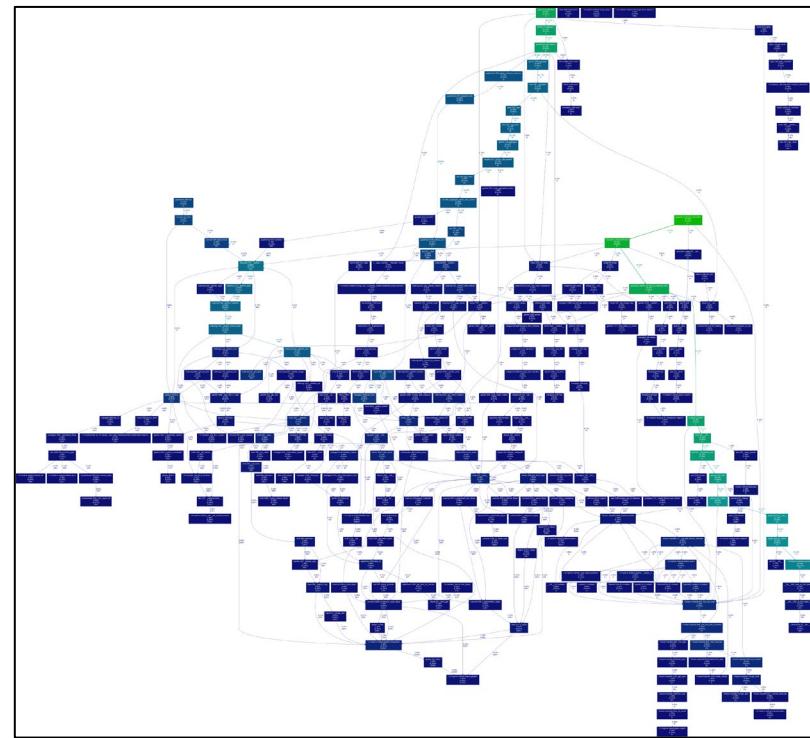


Roundtrip

Human Centered Methods +  
Task Categorization

# Our Specific Problem - Calling Context Tree Visualizations

```
0.000 foo
└─ 5.000 bar
  └─ 5.000 baz
    └─ 10.000 grault
└─ 0.000 quux
  └─ 5.000 quux
    └─ 10.000 corge
      └─ 5.000 bar
        └─ 5.000 baz
          └─ 10.000 grault
        └─ 10.000 grault
          └─ 15.000 garply
└─ 0.000 waldo
  └─ 5.000 fred
  └─ 5.000 plugh
  └─ 5.000 xyzzy
    └─ 5.000 thud
      └─ 5.000 baz
      └─ 15.000 garply
  └─ 15.000 garply
```



# Our Tasks for Calling Context Tree Analysis

[T1] Call Path Tracing

[T2] Tree Comparision

[T3] Metric Analysis

[T4] Tree Simplification

[T5] Save, Transfer, and Recover Modifications

Vis

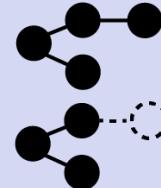
T1.1: Call Path Tracing



T1.2: Ancestor/Descendant Identification



T2.1: Tree Structure Comparision



T3.2: Meaningful Outlier Identification



T3.1: Single Metric Outlier Identification

```
print(  
    graphframe.tree(  
        metric_column="runtime"  
)
```

T4.1: Elide Irrelevant Subtrees



T4.2: Elide Nodes Based on Metric



T4.3: Function Identity Based Agg.

```
graphframe.compose_nodes(  
    node1 = "foo",  
    node2 = "bar",  
    new_node = "bar")
```



T5.1: Extract Tree State from Vis

```
{ "graph": [  
    { name: "foo",  
      children: ["bar", "baz"] }  
    ... ] }
```

T5.2: Store Tree State

```
with open("save.json", "w") as f:  
    f.write(tree_state)
```

T5.3: Recover Tree State

```
with open("save.json", "r") as f:  
    tree_state = f.read()  
    gf = graphframe.filter(tree_state)
```

Script

T2.2: Node Metric Comparision

```
df["gt_node"] =  
    gcc_df["time"] > llvm_df["time"]
```

T3.3: Scaling Analysis

```
df["speedup"] =  
    df["64_cores"] / df["4_cores"]
```

T4.4: Complex Criteria Filtering

```
graphframe.filter(  
    lambda x: "malloc" not in x["name"]  
)
```

# %cct for Hatchet

Hatchet  
(Scripting Side)



%cct ?graphframe ?selections\_and\_state

Metrics   Display   Query   Interactive Calling Context Tree

Legend for metric: speedup

■ 1.60 - 1.92
■ 1.28 - 1.60
■ 0.96 - 1.28
■ 0.64 - 0.96
■ 0.32 - 0.64
■ 0.00 - 0.32

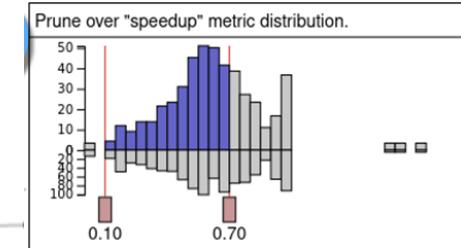
Legend for metric: time

○ 7.10M - 8.52M
○ 5.68M - 7.10M
○ 4.26M - 5.68M
○ 2.84M - 4.26M
○ 1.42M - 2.84M
○ 8.00 - 1.42M

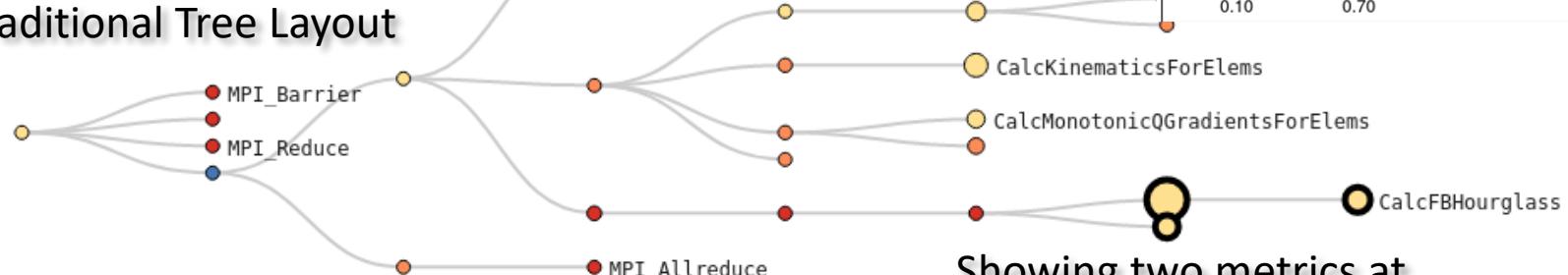
Detailed View on  
Selected Nodes

name	speedup	time	time (inc)
CalcFBHourglassForceForElems	0.79	3.83M	3.83M
IntegrateStressForElems	0.79	3.13M	3.13M
CalcHourglassControlForElems	0.64	8.52M	12.36M

Mass Prune



Traditional Tree Layout



Showing two metrics at  
once

## Calling Context Tree Example Notebook

```
In [1]: import os, sys  
from IPython.display import HTML, display  
  
import hatchet as ht  
%load_ext hatchet.vis.loader  
  
In [2]: gf = ht.GraphFrame.from_hpctoolkit('datasets/kripke-scaling/hpctoolkit-kripke-64-cores/*')  
  
In [ ]: %cct ?gf ?selections_and_state  
  
In [ ]: %table ?gf ?selections_and_state  
  
In [ ]:
```

## Calling Context Tree Example Notebook

```
In [ ]: import os, sys  
from IPython.display import HTML, display  
  
import hatchet as ht  
%load_ext hatchet.vis.loader
```

```
In [ ]: gf = ht.GraphFrame.from_hpctoolkit('datasets/kripke-scaling/hpctoolkit-kripke-64-cores/')
```

```
In [ ]: %cct gf
```

```
In [ ]:
```

## Calling Context Tree Example Notebook

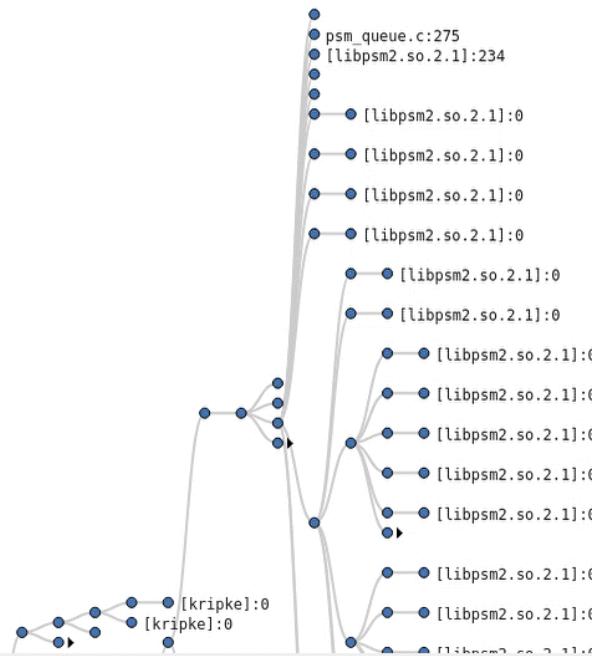
```
In [12]: import os, sys  
from IPython.display import HTML, display  
  
import hatchet as ht  
%load_ext hatchet.vis.loader  
  
The hatchet.vis.loader extension is already loaded. To reload it, use:  
%reload_ext hatchet.vis.loader
```

```
In [13]: gf = ht.GraphFrame.from_hpctoolkit('datasets/kripke-scaling/hpctoolkit-kripke-64-cores/')
```

```
In [14]: %cct gf
```

Metrics   Display   Query

Interactive Calling Context Tree



## Calling Context Tree Example Notebook

```
In [1]: import os, sys
from IPython.display import HTML, display

import hatchet as ht
%load_ext hatchet.vis.loader

In [2]: """
    The following are convenience functions provided to you for this tutorial, and define some common operations.
    They cannot operate on dataframes produced from eachother,
    so only use them on dataframes directly loaded from a dataset
"""

def affixColumnToGraphframe(dest_gf, src_gf, colname_dest, colname_src):
    """
        Attaches a column from one graph frame to another. Returns a new
        graphframe with the requested column.
        Note: will not produce meaningful results if node names and node id's are not aligned
        between datasets

    Params:
        dest_gf: the destination graphframe for the column
        src_gf: the source graphframe for the column
        colname_dest: the target column name on the destination graphframe
        colname_src: the name of the column we would like to transfer from source
    """
    gf_new = dest_gf.copy()
    src_gf = src_gf.copy()

    src_gf.dataframe[colname_dest] = src_gf.dataframe[colname_src]
    src_gf.dataframe = src_gf.dataframe.drop(columns=['time (inc)', 'time'])

    gf_new.dataframe = gf_new.dataframe \
        .reset_index() \
        .join(\`\
            src_gf.dataframe.reset_index().set_index(['nid','name']),\
            on=['nid','name'],\
            lsuffix='_l',\
            rsuffix='_r'
        )

    if('_missing_node' in gf_new.dataframe.columns):
        gf_new.dataframe = gf_new.dataframe.drop(columns=['_missing_node'])

    removes = [c for c in gf_new.dataframe.columns if '_r' in c]
    renames = {}

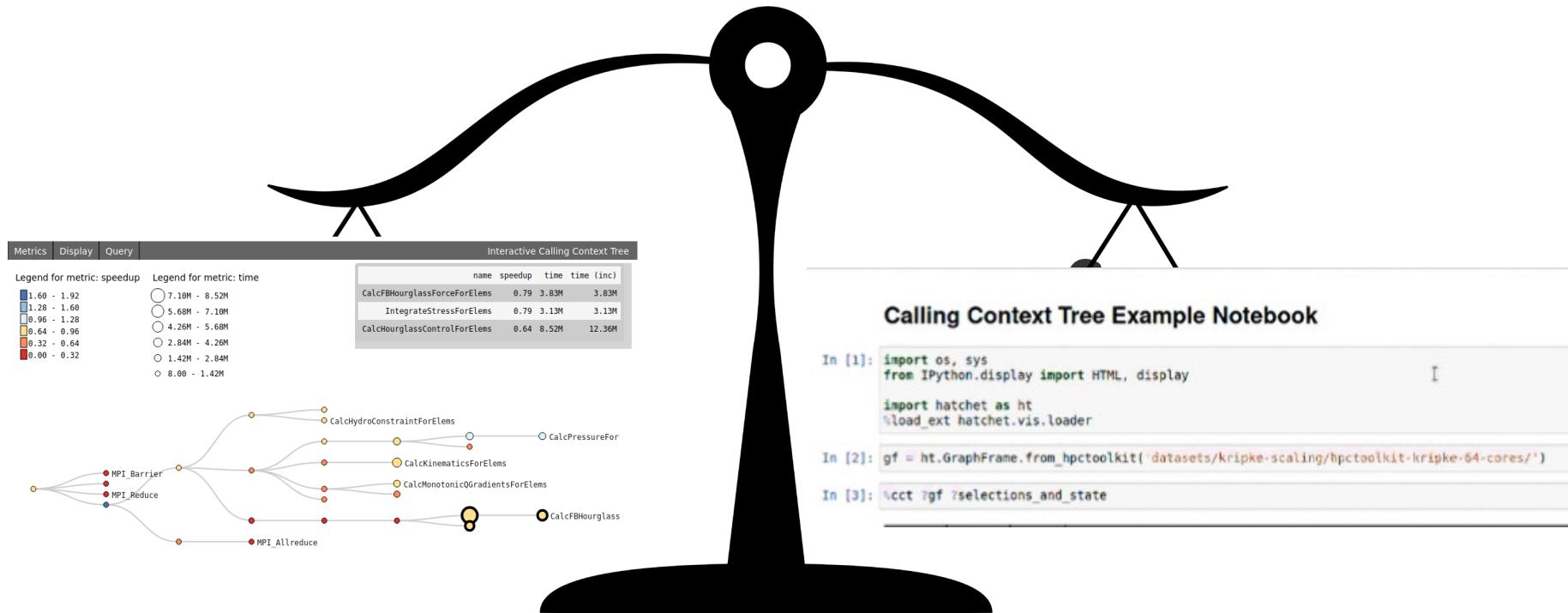
    for c in gf_new.dataframe.columns:
        if c[-2:] == '_l':
            renames[c] = c[:-2]

    gf_new.dataframe = gf_new.dataframe.drop(columns=removes).rename(columns=renames).set_index(['node'])

    gf_new.exc_metrics.append(colname_dest)

    return gf_new

def calcSpeedup(gf1, gf2):
    # Calculates the speedup between two graph frames
    # with the same function calls
```

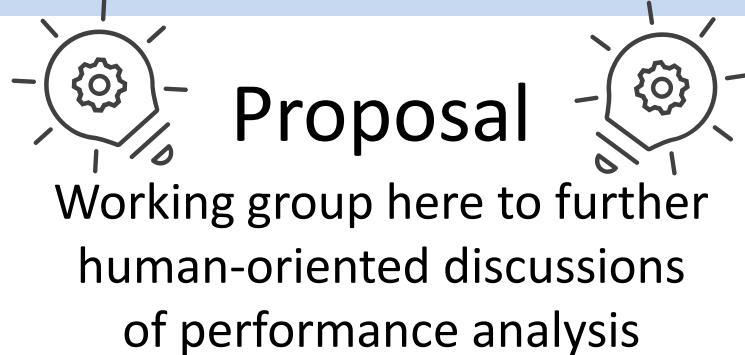


We want to integrate scripting and visualization better for this community to support their workflows.



Thicket

<https://github.com/LLNL/thicket>



Hatchet

<https://github.com/LLNL/hatchet>



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