hatchet Documentation

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User Docs

Hatchet is a Python-based library that allows Pandas dataframes to be indexed by structured tree and graph data. It is intended for analyzing performance data that has a hierarchy (for example, serial or parallel profiles that represent calling context trees, call graphs, nested regions' timers, etc.). Hatchet implements various operations to analyze a single hierarchical data set or compare multiple data sets, and its API facilitates analyzing such data programmatically.

You can get hatchet from its GitHub repository:

```
$ git clone https://github.com/LLNL/hatchet.git
```

or install it using pip:

```
$ pip install hatchet
```

If you are new to hatchet and want to start using it, see *Getting Started*, or refer to the full *User Guide* below.

CHAPTER 1

Getting Started

1.1 Prerequisites

Hatchet has the following minimum requirements, which must be installed before Hatchet is run:

1. Python 2 (2.7) or 3 (3.5 - 3.8)
2. matplotlib
3. pydot
4. numpy, and
5. pandas

Hatchet is available on GitHub.

1.2 Installation

You can get hatchet from its GitHub repository using this command:

```
$ git clone https://github.com/LLNL/hatchet.git
```

This will create a directory called `hatchet`.

1.2.1 Install and Build Hatchet

To build hatchet and update your PYTHONPATH, run the following shell script from the hatchet root directory:

```
$ source ./install.sh
```

Note: The `source` keyword is required to update your PYTHONPATH environment variable. It is not necessary if you have already manually added the hatchet directory to your PYTHONPATH.

Alternatively, you can install hatchet using pip:

```
$ pip install hatchet
```

1.2.2 Check Installation

After installing hatchet, you should be able to import hatchet when running the Python interpreter in interactive mode:

```
$ python
Python 3.7.4 (default, Jul 11 2019, 01:08:00)
[Clang 10.0.1 (clang-1001.0.46.4)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

Typing `import hatchet` at the prompt should succeed without any error messages:

```
>>> import hatchet
>>>
```

1.3 Supported data formats

Currently, hatchet supports the following data formats as input:

- HPCToolkit database: This is generated by using `hpcprof-mpi` to post-process the raw measurements directory output by HPCToolkit.
- Caliper Cali file: This is the format in which caliper outputs raw performance data by default.
- Caliper Json-split file: This is generated by either running cali-query on the raw caliper data or by enabling the mpireport service when using caliper.
- DOT format: This is generated by using gprof2dot on `gprof` or `callgrind` output.
- String literal: Hatchet can read as input a list of dictionaries that represents a graph.
- List: Hatchet can also read a list of lists that represents a graph.

For more details on the different input file formats, refer to the *User Guide*.

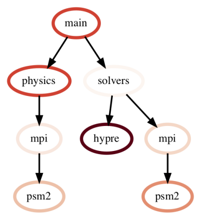
CHAPTER 2

User Guide

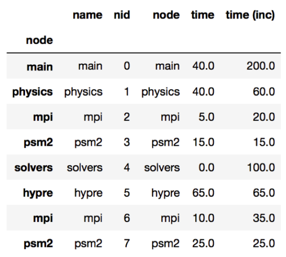
Hatchet is a Python tool that simplifies the process of analyzing hierarchical performance data such as calling context trees. Hatchet uses pandas dataframes to store the data on each node of the hierarchy and keeps the graph relationships between the nodes in a different data structure that is kept consistent with the dataframe.

2.1 Data structures in hatchet

Hatchet's primary data structure is a `GraphFrame`, which combines a structured index in the form of a graph with a pandas dataframe. The images on the right show the two objects in a `GraphFrame` – a `Graph` object (the index), and a `DataFrame object` storing the metrics associated with each node.



Graphframe stores the performance data that is read in from an HPCToolkit database, Caliper Json or Cali file, or gprof/callgrind DOT file. Typically, the raw input data is in the form of a tree. However, since subsequent operations on the tree can lead to new edges being created which can turn the tree into a graph, we store the input data as a directed graph. The graphframe consists of a graph object that stores the edge relationships between nodes and a dataframe that stores different metrics (numerical data) and categorical data associated with each node.



node	name	nid	node	time	time (inc)
main	main	0	main	40.0	200.0
physics	physics	1	physics	40.0	60.0
mpi	mpi	2	mpi	5.0	20.0
psm2	psm2	3	psm2	15.0	15.0
solvers	solvers	4	solvers	0.0	100.0
hypre	hypre	5	hypre	65.0	65.0
mpi	mpi	6	mpi	10.0	35.0
psm2	psm2	7	psm2	25.0	25.0

Graph: The graph can be connected or disconnected (multiple roots) and each node in the graph can have one or more parents and children. The node stores its frame, which can be defined by the reader. The callpath is derived by appending the frames from the root to a given node.

Dataframe: The dataframe holds all the numerical and categorical data associated with each node. Since typically the call tree data is per process, a multiindex composed of the node and MPI rank is used to index into the dataframe.

2.2 Reading in a dataset

One can use one of several static methods defined in the GraphFrame class to read in an input dataset using hatchet. For example, if a user has an HPCToolkit database directory that they want to analyze, they can use the `from_hpctoolkit` method:

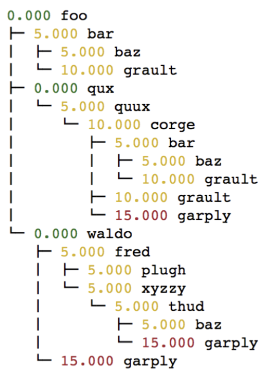
```
import hatchet as ht

if __name__ == "__main__":
    dirname = "hatchet/tests/data/hpctoolkit-cpi-database"
    gf = ht.GraphFrame.from_hpctoolkit(dirname)
```

Similarly if the input file is a split-JSON output by Caliper, they can use the `from_caliper_json` method:

```
import hatchet as ht

if __name__ == "__main__":
    filename = ("hatchet/tests/data/caliper-lulesh-json/lulesh-sample-annotation-
↪profile.json")
    gf = ht.GraphFrame.from_caliper_json(filename)
```

Examples of reading in other file formats can be found in *Analysis Examples*.

2.3 Visualizing the data

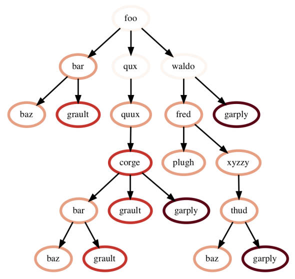


```
0.000 foo
├─ 5.000 bar
|  ├─ 5.000 baz
|  └─ 10.000 grault
├─ 0.000 qux
|  └─ 5.000 quux
|     └─ 10.000 corge
|        ├─ 5.000 bar
|        |  ├─ 5.000 baz
|        |  └─ 10.000 grault
|        ├─ 10.000 grault
|        └─ 15.000 garply
└─ 0.000 waldo
   ├─ 5.000 fred
   |  ├─ 5.000 plugh
   |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

When the graph represented by the input dataset is small, the user may be interested in visualizing it in entirety or a portion of it. Hatchet provides several mechanisms to visualize the graph in hatchet. One can use the `tree()` function to convert the graph into a string that can be printed on standard output:

```
print(gf.tree())
```

One can also use the `to_dot()` function to output the tree as a string in the Graphviz' DOT format. This can be written to a file and then used to display a tree using the `dot` or `neato` program.



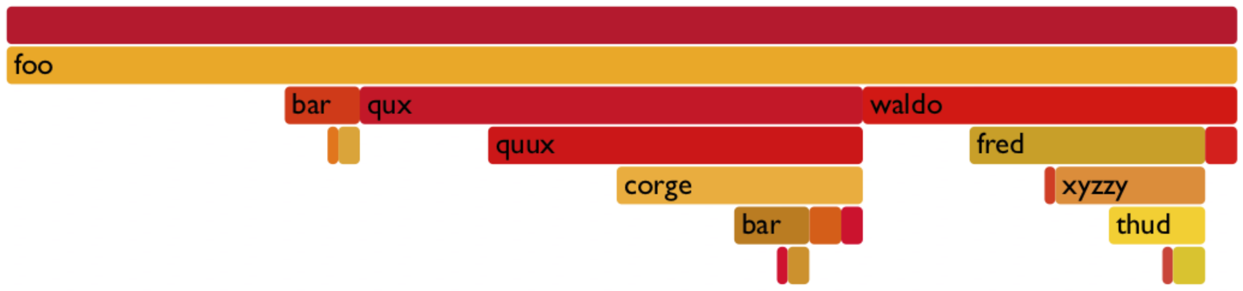
```
with open("test.dot", "w") as dot_file:
    dot_file.write(gf.to_dot())
```

```
$ dot -Tpdf test.dot > test.pdf
```

One can also use the `to_flamegraph` function to output the tree as a string in the folded stack format required by flamegraph. This file can then be used to create a flamegraph using `flamegraph.pl`.

```
with open("test.txt", "w") as folded_stack:
    folded_stack.write(gf.to_flamegraph())
```

```
$ ./flamegraph.pl test.txt > test.svg
```



One can also print the contents of the dataframe to standard output:

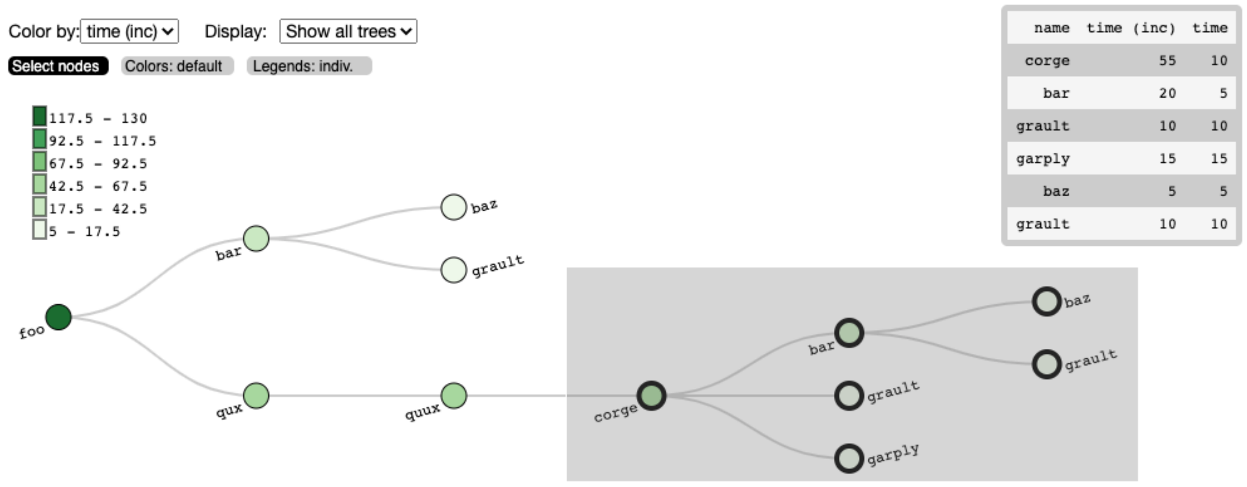
```
pd.set_option("display.width", 1200)
pd.set_option("display.max_colwidth", 20)
pd.set_option("display.max_rows", None)

print(gf.dataframe)
```

If there are many processes or threads in the dataframe, one can also print a cross section of the dataframe, say the values for rank 0, like this:

```
print(gf.dataframe.xs(0, level="rank"))
```

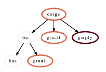
One can also view the graph in Hatchet's interactive visualization for Jupyter. In the Jupyter visualization shown below, users can explore their data by using their mouse to select and hide nodes. For those nodes selected, a table in the the upper right will display the metadata for the node(s) selected.

```
roundtrip_path = "hatchet/external/roundtrip/"
%load_ext roundtrip
%loadVisualization roundtrip_path literal_graph
```



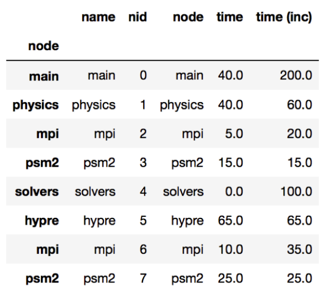
name	time (inc)	time
corge	55	10
bar	20	5
grault	10	10
garply	15	15
baz	5	5
grault	10	10

Once the user has explored their data, the interactive visualization can output the corresponding callpath query of the selected nodes. This query can then be integrated into future workflows to automate the filtering of the data by the query. For the selection above, we can save the resulting query and use it in Hatchet's `filter()` function to filter the input graph in a Python script. A code snippet is shown below, with the resulting filtered graph shown on the right. An example notebook of the interactive visualization can be found in the *docs/examples/tutorials* directory.



```
%fetchData myQuery
filter_gf = gf.filter(myQuery)
```

2.4 Dataframe operations

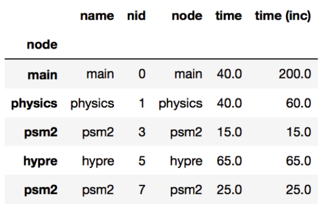


	name	nid	node	time	time (inc)
node					
main	main	0	main	40.0	200.0
physics	physics	1	physics	40.0	60.0
mpi	mpi	2	mpi	5.0	20.0
psm2	psm2	3	psm2	15.0	15.0
solvers	solvers	4	solvers	0.0	100.0
hypre	hypre	5	hypre	65.0	65.0
mpi	mpi	6	mpi	10.0	35.0
psm2	psm2	7	psm2	25.0	25.0

filter: `filter` takes a user-supplied function or query object and applies that to all rows in the DataFrame. The resulting Series or DataFrame is used to filter the DataFrame to only return rows that are true. The returned GraphFrame preserves the original graph provided as input to the filter operation.

```
filtered_gf = gf.filter(lambda x: x['time'] > 10.0)
```

The images on the right show a DataFrame before and after a filter operation.

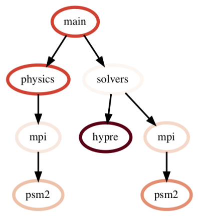


	name	nid	node	time	time (inc)
node					
main	main	0	main	40.0	200.0
physics	physics	1	physics	40.0	60.0
psm2	psm2	3	psm2	15.0	15.0
hypre	hypre	5	hypre	65.0	65.0
psm2	psm2	7	psm2	25.0	25.0

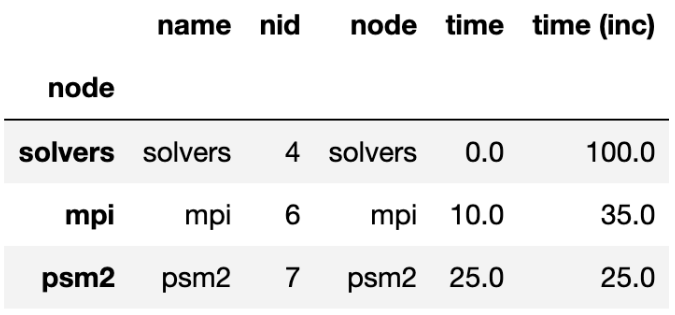
An alternative way to filter the DataFrame is to supply a query path in the form of a query object. A query object is a list of *abstract graph nodes* that specifies a call path pattern to search for in the GraphFrame. An *abstract graph node* is made up of two parts:

- A wildcard that specifies the number of real nodes to match to the abstract node. This is represented as either a string with value "." (match one node), "*" (match zero or more nodes), or "+" (match one or more nodes) or an integer (match exactly that number of nodes). By default, the wildcard is "." (or 1).
- A filter that is used to determine whether a real node matches the abstract node. In the high-level API, this is represented as a Python dictionary keyed on column names from the DataFrame. By default, the filter is an "always true" filter (represented as an empty dictionary).

The query object is represented as a Python list of abstract nodes. To specify both parts of an abstract node, use a tuple with the first element being the wildcard and the second element being the filter. To use a default value for either the wildcard or the filter, simply provide the other part of the abstract node on its own (no need for a tuple). The user **must** provide at least one of the parts of the above definition of an abstract node.



The query language example below looks for all paths that match first a single node with name *solvers*, followed by 0 or more nodes with an inclusive time greater than 10, followed by a single node with name that starts with *p* and ends in an integer and has an inclusive time greater than or equal to 10. When the query is used to filter and squash the the graph shown on the right, the returned GraphFrame contains the nodes shown in the table on the right.



	name	nid	node	time	time (inc)
node					
solvers	solvers	4	solvers	0.0	100.0
mpi	mpi	6	mpi	10.0	35.0
psm2	psm2	7	psm2	25.0	25.0

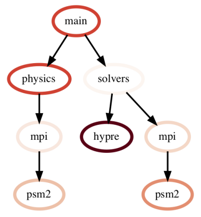
Filter is one of the operations that leads to the graph object and DataFrame object becoming inconsistent. After a filter operation, there are nodes in the graph that do not return any rows when used to index into the DataFrame. Typically, the user will perform a squash on the GraphFrame after a filter operation to make the graph and DataFrame objects consistent again. This can be done either by manually calling the `squash` function on the new GraphFrame or by setting the `squash` parameter of the `filter` function to `True`.

```
query = [
    {"name": "solvers"},
    ("*", {"time (inc)": "> 10"}),
    {"name": "p[a-z]+[0-9]", "time (inc)": ">= 10"}
]

filtered_gf = gf.filter(query)
```

drop_index_levels: When there is per-MPI process or per-thread data in the DataFrame, a user might be interested in aggregating the data in some fashion to analyze the graph at a coarser granularity. This function allows the user to drop the additional index columns in the hierarchical index by specifying an aggregation function. Essentially, this performs a `groupby` and `aggregate` operation on the DataFrame. The user-supplied function is used to perform the aggregation over all MPI processes or threads at the per-node granularity.

```
gf.drop_index_levels(function=np.max)
```

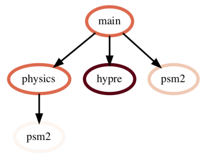
update_inclusive_columns: When a graph is rewired (i.e., the parent-child connections are modified), all the columns in the DataFrame that store inclusive values of a metric become inaccurate. This function performs a post-order traversal of the graph to update all columns that store inclusive metrics in the DataFrame for each node.



2.5 Graph operations

traverse: A generator function that performs a pre-order traversal of the graph and generates a sequence of all nodes in the graph in that order.

squash: The `squash` operation is typically performed by the user after a `filter` operation on the DataFrame. The squash operation removes nodes from the graph that were previously removed from the DataFrame due to a filter operation. When one or more nodes on a path are removed from the graph, the nearest remaining ancestor is connected by an edge to the nearest remaining child on the path. All call paths in the graph are re-wired in this manner.



A squash operation creates a new DataFrame in addition to the new graph. The new DataFrame contains all rows from the original DataFrame, but its index points to nodes in the new graph. Additionally, a squash operation will make the values in all columns containing inclusive metrics inaccurate, since the parent-child relationships have changed. Hence, the squash operation also calls `update_inclusive_columns` to make all inclusive columns in the DataFrame accurate again.

```
filtered_gf = gf.filter(lambda x: x['time'] > 10.0)
squashed_gf = filtered_gf.squash()
```

equal: The == operation checks whether two graphs have the same nodes and edge connectivity when traversing from their roots. If they are equivalent, it returns true, otherwise it returns false.

union: The `union` function takes two graphs and creates a unified graph, preserving all edges structure of the original graphs, and merging nodes with identical context. When Hatchet performs binary operations on two GraphFrames with unequal graphs, a union is performed beforehand to ensure that the graphs are structurally equivalent. This ensures that operands to element-wise operations like add and subtract, can be aligned by their respective nodes.

2.6 GraphFrame operations

copy: The `copy` operation returns a shallow copy of a GraphFrame. It creates a new GraphFrame with a copy of the original GraphFrame's DataFrame, but the same graph. As mentioned earlier, graphs in Hatchet use immutable semantics, and they are copied only when they need to be restructured. This property allows us to reuse graphs from GraphFrame to GraphFrame if the operations performed on the GraphFrame do not mutate the graph.

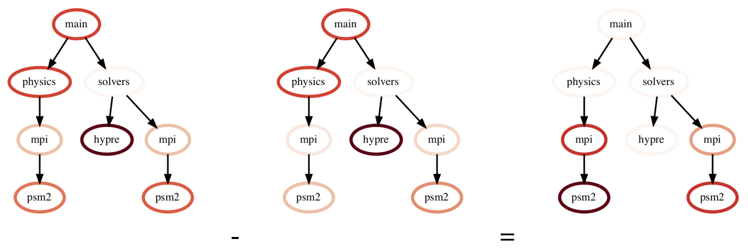
deepcopy: The `deepcopy` operation returns a deep copy of a GraphFrame. It is similar to `copy`, but returns a new GraphFrame with a copy of the original GraphFrame's DataFrame and a copy of the original GraphFrame's graph.

unify: `unify` operates on GraphFrames, and calls union on the two graphs, and then reindexes the DataFrames in both GraphFrames to be indexed by the nodes in the unified graph. Binary operations on GraphFrames call unify which in turn calls union on the respective graphs.

add: Assuming the graphs in two GraphFrames are equal, the `add (+)` operation computes the element-wise sum of two DataFrames. In the case where the two graphs are not identical, `unify` (described above) is applied first to create a unified graph before performing the sum. The DataFrames are copied and reindexed by the combined graph, and the add operation returns new GraphFrame with the result of adding these DataFrames. Hatchet also provides an in-place version of the add operator: +=.

subtract: The subtract operation is similar to the add operation in that it requires the two graphs to be identical. It applies `union` and reindexes DataFrames if necessary. Once the graphs are unified, the subtract operation computes the element-wise difference between the two DataFrames. The subtract operation returns a new GraphFrame, or it modifies one of the GraphFrames in place in the case of the in-place subtraction (-=).

```
gf1 = ht.GraphFrame.from_literal( ... )
gf2 = ht.GraphFrame.from_literal( ... )
gf2 -= gf1
```



tree: The `tree` operation returns the graphframe's graph structure as a string that can be printed to the console. By default, the tree uses the `name` of each node and the associated `time` metric as the string representation. This operation uses automatic color by default, but True or False can be used to force override.

CHAPTER 3

Analysis Examples

3.1 Reading different file formats

Hatchet can read in a variety of data file formats into a GraphFrame. Below, we show examples of reading in different data formats.

3.1.1 Read in an HPCToolkit database

A database directory is generated by using `hpcprof-mpi` to post-process the raw measurements directory output by HPCToolkit. To analyze an HPCToolkit database, the `from_hpctoolkit` method can be used.

```
#!/usr/bin/env python

import hatchet as ht


if __name__ == "__main__":
    # Path to HPCToolkit database directory.
    dirname = "../../../hatchet/tests/data/hpctoolkit-cpi-database"

    # Use hatchet's ``from_hpctoolkit`` API to read in the HPCToolkit database.
    # The result is stored into Hatchet's GraphFrame.
    gf = ht.GraphFrame.from_hpctoolkit(dirname)

    # Printout the DataFrame component of the GraphFrame.
    print(gf.dataframe)

    # Printout the graph component of the GraphFrame.
    # Use "time (inc)" as the metric column to be displayed
    print(gf.tree(metric_column="time (inc)"))
```

3.1.2 Read in a Caliper cali file

Caliper's default raw performance data output is the cali. The cali format can be read by `cali-query`, which transforms the raw data into JSON format.

```
#!/usr/bin/env python

import hatchet as ht


if __name__ == "__main__":
    # Path to caliper cali file.
    cali_file = (
        "../../../hatchet/tests/data/caliper-lulesh-cali/lulesh-annotation-profile.
↪cali"
    )

    # Setup desired cali query.
    grouping_attribute = "function"
    default_metric = "sum(sum#time.duration),inclusive_sum(sum#time.duration)"
    query = "select function,%s group by %s format json-split" % (
        default_metric,
        grouping_attribute,
    )

    # Use hatchet's ``from_caliper`` API with the path to the cali file and the
    # query. This API will internally run ``cali-query`` on this file to
    # produce a json-split stream. The result is stored into Hatchet's
    # GraphFrame.
    gf = ht.GraphFrame.from_caliper(cali_file, query)

    # Printout the DataFrame component of the GraphFrame.
    print(gf.dataframe)

    # Printout the graph component of the GraphFrame.
    # Use "time (inc)" as the metric column to be displayed
    print(gf.tree(metric_column="time (inc)"))
```

3.1.3 Read in a Caliper JSON stream or file

Caliper's json-split format writes a JSON file with separate fields for Caliper records and metadata. The json-split format is generated by either running `cali-query` on the raw Caliper data or by enabling the `mpireport` service when using Caliper.

JSON Stream

```
#!/usr/bin/env python

import subprocess
import hatchet as ht


if __name__ == "__main__":
    # Path to caliper cali file.
```

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```
    cali_file = (
        "../../../hatchet/tests/data/caliper-lulesh-cali/lulesh-annotation-profile.
↪cali"
    )

    # Setup desired cali query.
    cali_query = "cali-query"
    grouping_attribute = "function"
    default_metric = "sum(sum#time.duration),inclusive_sum(sum#time.duration)"
    query = "select function,%s group by %s format json-split" % (
        default_metric,
        grouping_attribute,
    )

    # Use ``cali-query`` here to produce the json-split stream.
    cali_json = subprocess.Popen(
        [cali_query, "-q", query, cali_file], stdout=subprocess.PIPE
    )

    # Use hatchet's ``from_caliper_json`` API with the resulting json-split.
    # The result is stored into Hatchet's GraphFrame.
    gf = ht.GraphFrame.from_caliper_json(cali_json.stdout)

    # Printout the DataFrame component of the GraphFrame.
    print(gf.dataframe)

    # Printout the graph component of the GraphFrame.
    # Use "time (inc)" as the metric column to be displayed
    print(gf.tree(metric_column="time (inc)"))
```

JSON File

```
#!/usr/bin/env python

import hatchet as ht


if __name__ == "__main__":
    # Path to caliper json-split file.
    json_file = "../../../hatchet/tests/data/caliper-cpi-json/cpi-callpath-profile.
↪json"

    # Use hatchet's ``from_caliper_json`` API with the resulting json-split.
    # The result is stored into Hatchet's GraphFrame.
    gf = ht.GraphFrame.from_caliper_json(json_file)

    # Printout the DataFrame component of the GraphFrame.
    print(gf.dataframe)

    # Printout the graph component of the GraphFrame.
    # Because no metric parameter is specified, ``time`` is used by default.
    print(gf.tree())
```

3.1.4 Read in a DOT file

The DOT file format is generated by using `gprof2dot` on `gprof` or `callgrind` output.

```
#!/usr/bin/env python

import hatchet as ht


if __name__ == "__main__":
    # Path to DOT file.
    dot_file = "../../../hatchet/tests/data/gprof2dot-cpi/callgrind.dot.64042.0.1"

    # Use hatchet's ``from_gprof_dot`` API to read in the DOT file. The result
    # is stored into Hatchet's GraphFrame.
    gf = ht.GraphFrame.from_gprof_dot(dot_file)

    # Printout the DataFrame component of the GraphFrame.
    print(gf.dataframe)

    # Printout the graph component of the GraphFrame.
    # Because no metric parameter is specified, ``time`` is used by default.
    print(gf.tree())
```

3.1.5 Read in a DAG literal

The literal format is a list of dictionaries representing a graph with nodes and metrics.

```
#!/usr/bin/env python
# -*- encoding: utf-8 -*-

import hatchet as ht


if __name__ == "__main__":
    # Define a literal GraphFrame using a list of dicts.
    gf = ht.GraphFrame.from_literal(
        [
            {
                "frame": {"name": "foo"},
                "metrics": {"time (inc)": 130.0, "time": 0.0},
                "children": [
                    {
                        "frame": {"name": "bar"},
                        "metrics": {"time (inc)": 20.0, "time": 5.0},
                        "children": [
                            {
                                "frame": {"name": "baz"},
                                "metrics": {"time (inc)": 5.0, "time": 5.0},
                            },
                            {
                                "frame": {"name": "grault"},
                                "metrics": {"time (inc)": 10.0, "time": 10.0},
                            },
                        ],
                    },
```

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```
                    {
                        "frame": {"name": "qux"},
                        "metrics": {"time (inc)": 60.0, "time": 0.0},
                        "children": [
                            {
                                "frame": {"name": "quux"},
                                "metrics": {"time (inc)": 60.0, "time": 5.0},
                                "children": [
                                    {
                                        "frame": {"name": "corge"},
                                        "metrics": {"time (inc)": 55.0, "time": 10.0},
                                        "children": [
                                            {
                                                "frame": {"name": "bar"},
                                                "metrics": {
                                                    "time (inc)": 20.0,
                                                    "time": 5.0,
                                                },
                                                "children": [
                                                    {
                                                        "frame": {"name": "baz"},
                                                        "metrics": {
                                                            "time (inc)": 5.0,
                                                            "time": 5.0,
                                                        },
                                                    },
                                                    {
                                                        "frame": {"name": "grault"},
                                                        "metrics": {
                                                            "time (inc)": 10.0,
                                                            "time": 10.0,
                                                        },
                                                    },
                                                ],
                                            },
                                            {
                                                "frame": {"name": "grault"},
                                                "metrics": {
                                                    "time (inc)": 10.0,
                                                    "time": 10.0,
                                                },
                                            },
                                            {
                                                "frame": {"name": "garply"},
                                                "metrics": {
                                                    "time (inc)": 15.0,
                                                    "time": 15.0,
                                                },
                                            },
                                        ],
                                    }
                                ],
                            }
                        ],
                    },
                    {
                        "frame": {"name": "waldo"},
```

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```
                        "metrics": {"time (inc)": 50.0, "time": 0.0},
                        "children": [
                            {
                                "frame": {"name": "fred"},
                                "metrics": {"time (inc)": 35.0, "time": 5.0},
                                "children": [
                                    {
                                        "frame": {"name": "plugh"},
                                        "metrics": {"time (inc)": 5.0, "time": 5.0},
                                    },
                                    {
                                        "frame": {"name": "xyzzy"},
                                        "metrics": {"time (inc)": 25.0, "time": 5.0},
                                        "children": [
                                            {
                                                "frame": {"name": "thud"},
                                                "metrics": {
                                                    "time (inc)": 25.0,
                                                    "time": 5.0,
                                                },
                                                "children": [
                                                    {
                                                        "frame": {"name": "baz"},
                                                        "metrics": {
                                                            "time (inc)": 5.0,
                                                            "time": 5.0,
                                                        },
                                                    },
                                                    {
                                                        "frame": {"name": "garply"},
                                                        "metrics": {
                                                            "time (inc)": 15.0,
                                                            "time": 15.0,
                                                        },
                                                    },
                                                ],
                                            }
                                        ],
                                    },
                                ],
                            },
                            {
                                "frame": {"name": "garply"},
                                "metrics": {"time (inc)": 15.0, "time": 15.0},
                            },
                        ],
                    },
                ],
            },
            {
                "frame": {"name": " (hoge)"},
                "metrics": {"time (inc)": 30.0, "time": 0.0},
                "children": [
                    {
                        "frame": {"name": "( (piyo)"},
                        "metrics": {"time (inc)": 15.0, "time": 5.0},
                        "children": [
```

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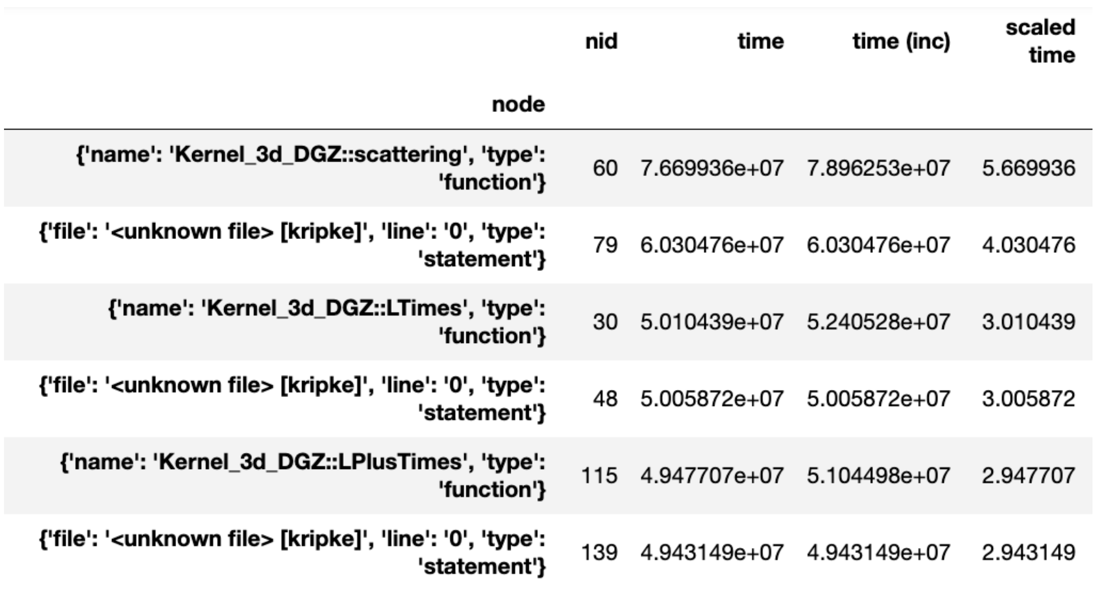
```
                            {
                                "frame": {"name": " (fuga)"},
                                "metrics": {"time (inc)": 5.0, "time": 5.0},
                            },
                            {
                                "frame": {"name": " (hogera)"},
                                "metrics": {"time (inc)": 5.0, "time": 5.0},
                            },
                        ],
                    },
                    {
                        "frame": {"name": " (hogehoge)"},
                        "metrics": {"time (inc)": 15.0, "time": 15.0},
                    },
                ],
            },
        ]
    )

    # Printout the DataFrame component of the GraphFrame.
    print(gf.dataframe)

    # Printout the graph component of the GraphFrame.
    # Because no metric parameter is specified, ``time`` is used by default.
    print(gf.tree())
```

3.2 Basic Examples

3.2.1 Applying scalar operations to attributes

Individual numeric columns in the dataframe can be scaled or offset by a constant using the native pandas operations. We make a copy of the original graphframe, and modify the dataframe directly. In this example, we offset the `time` column by -2 and scale it by 1/1e7, storing the result in a new column in the dataframe called `scaled time`.

```
gf = ht.GraphFrame.from_hpctoolkit('kripke')
gf.drop_index_levels()

offset = 1e7
gf.dataframe['scaled time'] = (gf.dataframe['time'] / offset) - 2
sorted_df = gf.dataframe.sort_values(by=['scaled time'], ascending=False)
print(sorted_df)
```



	nid	time	time (inc)	scaled time
node				
{'name': 'Kernel_3d_DGZ::scattering', 'type': 'function'}	60	7.669936e+07	7.896253e+07	5.669936
{'file': '<unknown file> [kripke]', 'line': '0', 'type': 'statement'}	79	6.030476e+07	6.030476e+07	4.030476
{'name': 'Kernel_3d_DGZ::LTimes', 'type': 'function'}	30	5.010439e+07	5.240528e+07	3.010439
{'file': '<unknown file> [kripke]', 'line': '0', 'type': 'statement'}	48	5.005872e+07	5.005872e+07	3.005872
{'name': 'Kernel_3d_DGZ::LPlusTimes', 'type': 'function'}	115	4.947707e+07	5.104498e+07	2.947707
{'file': '<unknown file> [kripke]', 'line': '0', 'type': 'statement'}	139	4.943149e+07	4.943149e+07	2.943149

3.2.2 Generating a flat profile

We can generate a flat profile in hatchet by using the `groupby` functionality in pandas. The flat profile can be based on any categorical column (e.g., function name, load module, file name). We can transform the tree or graph generated by a profiler into a flat profile by specifying the column on which to apply the `groupby` operation and the function to use for aggregation.

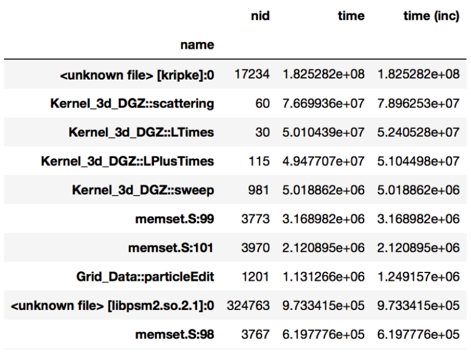
In the example below, we apply a pandas `groupby` operation on the `name` column. The time spent in each function is computed using `sum` to aggregate rows in a group. We then display the resulting DataFrame sorted by time.

```python
# Read in Kripke HPCToolkit database.
gf = ht.GraphFrame.from_hpctoolkit('kripke')

# Drop all index levels in the DataFrame except ``node``.
gf.drop_index_levels()

# Group DataFrame by ``name`` column, compute sum of all rows in each
# group. This shows the aggregated time spent in each function.
grouped = gf.dataframe.groupby('name').sum()

# Sort DataFrame by ``time`` column in descending order.
sorted_df = grouped.sort_values(by=['time'],
                                ascending=False)

# Display resulting DataFrame.
print(sorted_df)
```

3.2.3 Identifying load imbalance

Hatchet makes it extremely easy to study load imbalance across processes or threads at the per-node granularity (call site or function level). A typical metric to measure imbalance is to look at the ratio of the maximum and average time spent in a code region across all processes.

In this example, we ran LULESH across 512 cores, and are interested in understanding the imbalance across processes. We first perform a `drop_index_levels` operation on the GraphFrame in two different ways: (1) by providing



name	nid	time	time (inc)
<unknown file> [kripke]:0	17234	1.825282e+08	1.825282e+08
Kernel_3d_DGZ::scattering	60	7.669936e+07	7.896253e+07
Kernel_3d_DGZ::LTimes	30	5.010439e+07	5.240528e+07
Kernel_3d_DGZ::LPlusTimes	115	4.947707e+07	5.104498e+07
Kernel_3d_DGZ::sweep	981	5.018862e+06	5.018862e+06
memset.S:99	3773	3.168982e+06	3.168982e+06
memset.S:101	3970	2.120895e+06	2.120895e+06
Grid_Data::particleEdit	1201	1.131266e+06	1.249157e+06
<unknown file> [libpsm2.so.2.1]:0	324763	9.733415e+05	9.733415e+05
memset.S:98	3767	6.197776e+05	6.197776e+05

Fig. 1: Figure 1: Resulting DataFrame after performing a groupby on the `name` column in this HPCToolkit dataset (only showing a handful of rows for brevity). The DataFrame is sorted in descending order by the `time` column to show the function name with the biggest execution time.

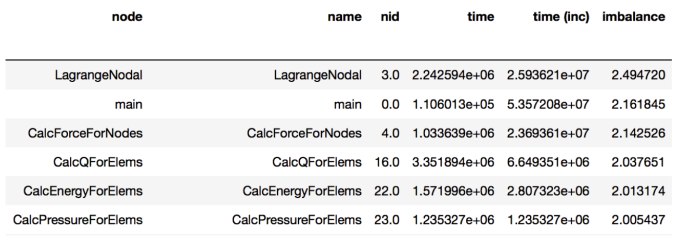
mean as a function in one case, and (2) max as the function to another copy of the DataFrame. This generates two DataFrames, one containing the average time spent in each node, and the other containing the maximum time spent in each node by any process. If we divide the corresponding columns of the two DataFrames and look at the nodes with the highest value of the max-to-average ratio, we can identify the nodes with highest imbalance.

```python
# Read in LULESH Caliper dataset.
gf1 = ht.GraphFrame.from_caliper('lulesh-512cores')

# Create a copy of the GraphFrame.
gf2 = gf1.copy()

# Drop all index levels in gf1's DataFrame except ``node``, computing the
# average time spent in each node.
gf1.drop_index_levels(function=np.mean)

# Drop all index levels in a copy of gf1's DataFrame except ``node``, this
# time computing the max time spent in each node.
gf2.drop_index_levels(function=np.max)

# Compute the imbalance by dividing the ``time`` column in the max DataFrame
# (i.e., gf2) by the average DataFrame (i.e., gf1). This creates a new column
# called ``imbalance`` in gf1's DataFrame.
gf1.dataframe['imbalance'] = gf2.dataframe['time'].div(gf1.dataframe['time'])

# Sort DataFrame by ``imbalance`` column in descending order.
sorted_df = gf1.dataframe.sort_values(by=['imbalance'], ascending=False)

# Display resulting DataFrame.
print(sorted_df)
```

3.2.4 Comparing multiple executions

An important task in parallel performance analysis is comparing the performance of an application on two different thread counts or process counts. The `filter`, `squash`, and `subtract` operations provided by the Hatchet API can be extremely powerful in comparing profiling datasets from two executions.

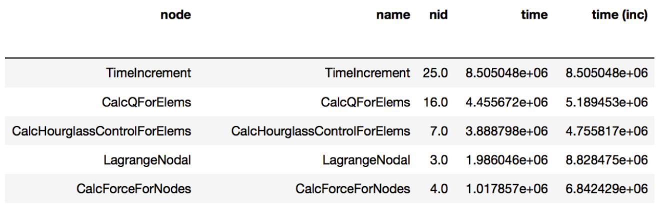
In the example below, we ran LULESH at two core counts: 1 core and 27 cores, and wanted to identify the performance changes as one scales on a node. We subtract the GraphFrame at 27 cores from the GraphFrame at 1 core (after dropping the additional index levels), and sort the resulting GraphFrame by execution time.



node	name	nid	time	time (inc)	imbalance
LagrangeNodal	LagrangeNodal	3.0	2.242594e+06	2.593621e+07	2.494720
main	main	0.0	1.106013e+05	5.357208e+07	2.161845
CalcForceForNodes	CalcForceForNodes	4.0	1.033639e+06	2.369361e+07	2.142526
CalcQForElems	CalcQForElems	16.0	3.351894e+06	6.649351e+06	2.037651
CalcEnergyForElems	CalcEnergyForElems	22.0	1.571996e+06	2.807323e+06	2.013174
CalcPressureForElems	CalcPressureForElems	23.0	1.235327e+06	1.235327e+06	2.005437

Fig. 2: Figure 2: Resulting DataFrame showing the imbalance in this Caliper dataset (only showing a handful of rows for brevity). The DataFrame is sorted in descending order by the new `imbalance` column calculated by dividing the max/average time of each function. The function with the highest level of imbalance within a node is `LagrangeNodal` with an imbalance of 2.49.

```python
# Read in LULESH Caliper dataset at 1 core.
gf1 = ht.GraphFrame.from_caliper('lulesh-1core.json')

# Read in LULESH Caliper dataset at 27 cores.
gf2 = ht.GraphFrame.from_caliper('lulesh-27cores.json')

# Drop all index levels in gf2's DataFrame except ``node``.
gf2.drop_index_levels()

# Subtract the GraphFrame at 27 cores from the GraphFrame at 1 core, and
# store result in a new GraphFrame.
gf3 = gf2 - gf1

# Sort resulting DataFrame by ``time`` column in descending order.
sorted_df = gf3.dataframe.sort_values(by=['time'], ascending=False)

# Display resulting DataFrame.
print(sorted_df)
```



node	name	nid	time	time (inc)
TimeIncrement	TimeIncrement	25.0	8.505048e+06	8.505048e+06
CalcQForElems	CalcQForElems	16.0	4.455672e+06	5.189453e+06
CalcHourglassControlForElems	CalcHourglassControlForElems	7.0	3.888798e+06	4.755817e+06
LagrangeNodal	LagrangeNodal	3.0	1.986046e+06	8.828475e+06
CalcForceForNodes	CalcForceForNodes	4.0	1.017857e+06	6.842429e+06

Fig. 3: Figure 3: Resulting DataFrame showing the performance differences when running LULESH at 1 core vs. 27 cores (only showing a handful of rows for brevity). The DataFrame sorts the function names in descending order by the `time` column. The `TimeIncrement` has the largest difference in execution time of 8.5e6 as the code scales from 1 to 27 cores.

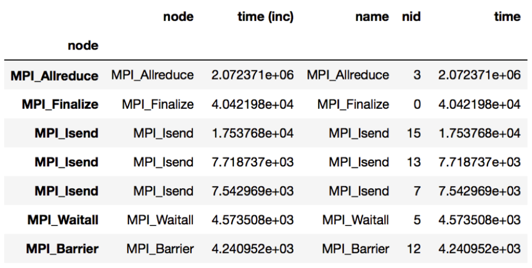
3.2.5 Filtering by library

Sometimes, users are interested in analyzing how a particular library, such as PetSc or MPI, is used by their application and how the time spent in the library changes as we scale to a larger number of processes.

In this next example, we compare two datasets generated from executions at different numbers of MPI processes. We read in two datasets of LULESH at 27 and 512 MPI processes, respectively, and filter them both on the `name` column by matching the names against `^MPI`. After the filtering operation, we `squash` the DataFrames to generate

GraphFrames that just contain the MPI calls from the original datasets. We can now subtract the squashed datasets to identify the biggest offenders.

```
# Read in LULESH Caliper dataset at 27 cores.
gf1 = GraphFrame.from_caliper('lulesh-27cores')

# Drop all index levels in DataFrame except ``node``.
gf1.drop_index_levels()

# Filter GraphFrame by names that start with ``MPI``. This only filters the #
# DataFrame. The Graph and DataFrame are now out of sync.
filtered_gf1 = gf1.filter(lambda x: x['name'].startswith('MPI'))

# Squash GraphFrame, the nodes in the Graph now match what's in the
# DataFrame.
squashed_gf1 = filtered_gf1.squash()

# Read in LULESH Caliper dataset at 512 cores, drop all index levels except
# ``node``, filter and squash the GraphFrame, leaving only nodes that start
# with ``MPI``.
gf2 = GraphFrame.from_caliper('lulesh-512cores')
gf2.drop_index_levels()
filtered_gf2 = gf2.filter(lambda x: x['name'].startswith('MPI'))
squashed_gf2 = filtered_gf2.squash()

# Subtract the two GraphFrames, store the result in a new GraphFrame.
diff_gf = squashed_gf2 - squashed_gf1

# Sort resulting DataFrame by ``time`` column in descending order.
sorted_df = diff_gf.dataframe.sort_values(by=['time'], ascending=False)

# Display resulting DataFrame.
print(sorted_df)
```



	node	time (inc)	name	nid	time
node					
MPI_Allreduce	MPI_Allreduce	2.072371e+06	MPI_Allreduce	3	2.072371e+06
MPI_Finalize	MPI_Finalize	4.042198e+04	MPI_Finalize	0	4.042198e+04
MPI_Isend	MPI_Isend	1.753768e+04	MPI_Isend	15	1.753768e+04
MPI_Isend	MPI_Isend	7.718737e+03	MPI_Isend	13	7.718737e+03
MPI_Isend	MPI_Isend	7.542969e+03	MPI_Isend	7	7.542969e+03
MPI_Waitall	MPI_Waitall	4.573508e+03	MPI_Waitall	5	4.573508e+03
MPI_Barrier	MPI_Barrier	4.240952e+03	MPI_Barrier	12	4.240952e+03

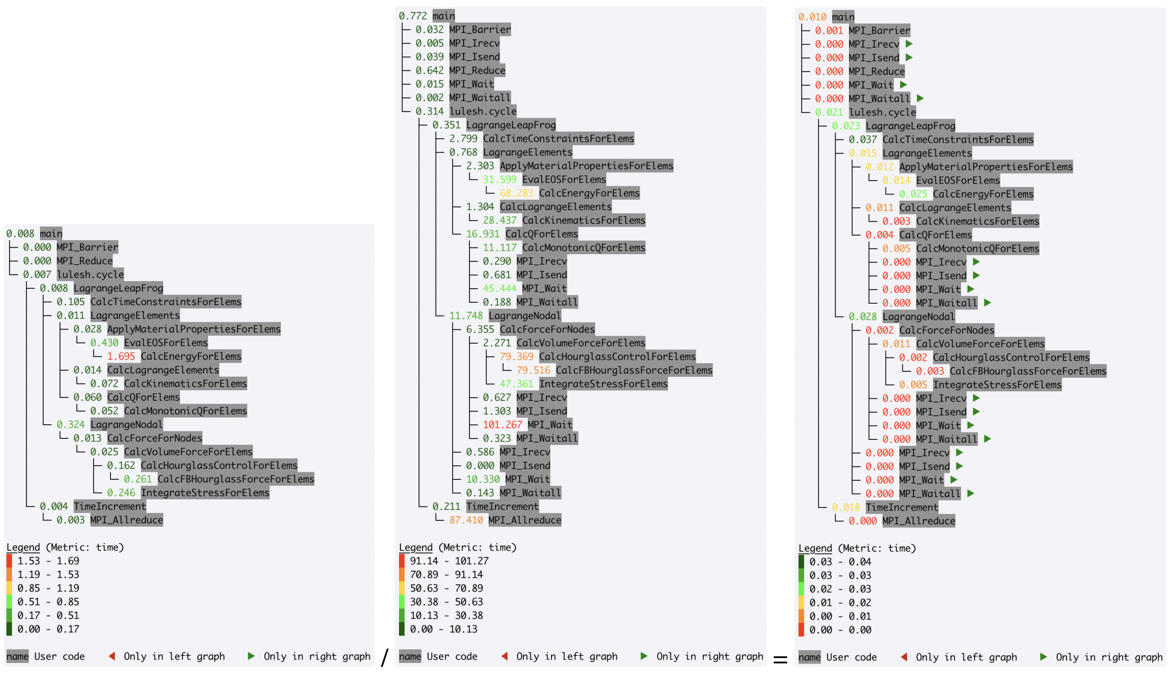
Fig. 4: Figure 4: Resulting DataFrame showing the MPI performance differences when running LULESH at 27 cores vs. 512 cores. The DataFrame sorts the MPI functions in descending order by the `time` column. In this example, the `MPI_Allreduce` function sees the largest increase in time scaling from 27 to 512 cores.

3.3 Scaling Performance Examples

3.3.1 Analyzing strong scaling performance

Hatchet can be used for a strong scaling analysis of applications. In this example, we compare the performance of LULESH running on 1 and 64 cores. By executing a simple `divide` of the two datasets in Hatchet, we can quickly pinpoint bottleneck functions. In the resulting graph, we invert the color scheme, so that functions that did not scale well (i.e., have a low speedup) are colored in red.

```
gf_1core = ht.GraphFrame.from_caliper('lulesh*-1core.json')
gf_64cores = ht.GraphFrame.from_caliper('lulesh*-64cores.json')

gf_64cores["time"] *= 64

gf_strong_scale = gf_1core / gf_64cores
```



```
0.008 main
├─ 0.000 MPI_Barrier
├─ 0.000 MPI_Reduce
└─ 0.007 lulesh.cycle
   ├─ 0.008 LagrangeLeapFrog
   │  ├─ 0.105 CalcTimeConstraintsForElems
   │  ├─ 0.011 LagrangeElements
   │  │  ├─ 0.028 ApplyMaterialPropertiesForElems
   │  │  │  └─ 0.430 EvalEOSForElems
   │  │  │     └─ 1.695 CalcEnergyForElems
   │  │  ├─ 0.014 CalcLagrangeElements
   │  │  │  └─ 0.072 CalcKinematicsForElems
   │  │  └─ 0.060 CalcQForElems
   │  │     └─ 0.052 CalcMonotonicQForElems
   │  └─ 0.324 LagrangeNodal
   │     └─ 0.013 CalcForceForNodes
   │        └─ 0.025 CalcVolumeForceForElems
   │           ├─ 0.162 CalcHourglassControlForElems
   │           │  └─ 0.261 CalcFBHourglassForceForElems
   │           └─ 0.246 IntegrateStressForElems
   └─ 0.004 TimeIncrement
      └─ 0.003 MPI_Allreduce

Legend (Metric: time)
🟥 1.53 - 1.69
🟧 1.19 - 1.53
🟨 0.85 - 1.19
🟩 0.51 - 0.85
🟩 0.17 - 0.51
🟩 0.00 - 0.17

name User code    ◀ Only in left graph    ▶ Only in right graph
```

/

```
0.772 main
├─ 0.032 MPI_Barrier
├─ 0.005 MPI_Irecv
├─ 0.039 MPI_Isend
├─ 0.642 MPI_Reduce
├─ 0.015 MPI_Wait
├─ 0.002 MPI_Waitall
└─ 0.314 lulesh.cycle
   ├─ 0.351 LagrangeLeapFrog
   │  ├─ 2.799 CalcTimeConstraintsForElems
   │  ├─ 0.768 LagrangeElements
   │  │  ├─ 2.303 ApplyMaterialPropertiesForElems
   │  │  │  └─ 31.599 EvalEOSForElems
   │  │  │     └─ 68.283 CalcEnergyForElems
   │  │  ├─ 1.304 CalcLagrangeElements
   │  │  │  └─ 28.437 CalcKinematicsForElems
   │  │  └─ 16.931 CalcQForElems
   │  │     ├─ 11.117 CalcMonotonicQForElems
   │  │     ├─ 0.290 MPI_Irecv
   │  │     ├─ 0.681 MPI_Isend
   │  │     ├─ 45.444 MPI_Wait
   │  │     └─ 0.188 MPI_Waitall
   │  └─ 11.748 LagrangeNodal
   │     ├─ 6.355 CalcForceForNodes
   │     │  ├─ 2.271 CalcVolumeForceForElems
   │     │  │  ├─ 79.369 CalcHourglassControlForElems
   │     │  │  │  └─ 79.516 CalcFBHourglassForceForElems
   │     │  │  └─ 47.361 IntegrateStressForElems
   │     │  ├─ 0.627 MPI_Irecv
   │     │  ├─ 1.303 MPI_Isend
   │     │  ├─ 101.267 MPI_Wait
   │     │  └─ 0.323 MPI_Waitall
   │     ├─ 0.586 MPI_Irecv
   │     ├─ 0.000 MPI_Isend
   │     ├─ 10.330 MPI_Wait
   │     └─ 0.143 MPI_Waitall
   └─ 0.211 TimeIncrement
      └─ 87.410 MPI_Allreduce

Legend (Metric: time)
🟥 91.14 - 101.27
🟧 70.89 - 91.14
🟨 50.63 - 70.89
🟩 30.38 - 50.63
🟩 10.13 - 30.38
🟩 0.00 - 10.13

name User code    ◀ Only in left graph    ▶ Only in right graph
```

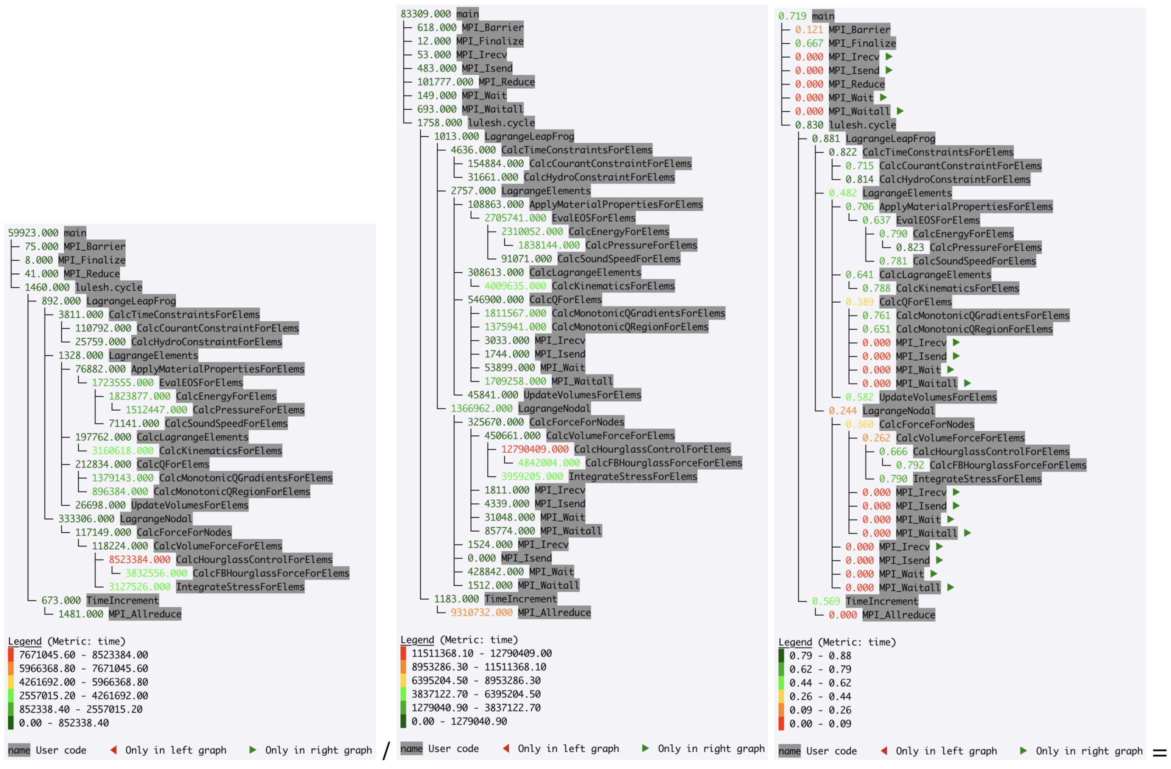
=

```
0.010 main
├─ 0.001 MPI_Barrier
├─ 0.000 MPI_Irecv ▶
├─ 0.000 MPI_Isend ▶
├─ 0.000 MPI_Reduce
├─ 0.000 MPI_Wait ▶
├─ 0.000 MPI_Waitall ▶
└─ 0.021 lulesh.cycle
   ├─ 0.023 LagrangeLeapFrog
   │  ├─ 0.037 CalcTimeConstraintsForElems
   │  ├─ 0.015 LagrangeElements
   │  │  ├─ 0.012 ApplyMaterialPropertiesForElems
   │  │  │  └─ 0.014 EvalEOSForElems
   │  │  │     └─ 0.025 CalcEnergyForElems
   │  │  ├─ 0.011 CalcLagrangeElements
   │  │  │  └─ 0.003 CalcKinematicsForElems
   │  │  └─ 0.004 CalcQForElems
   │  │     ├─ 0.005 CalcMonotonicQForElems
   │  │     ├─ 0.000 MPI_Irecv ▶
   │  │     ├─ 0.000 MPI_Isend ▶
   │  │     ├─ 0.000 MPI_Wait ▶
   │  │     └─ 0.000 MPI_Waitall ▶
   │  └─ 0.028 LagrangeNodal
   │     ├─ 0.002 CalcForceForNodes
   │     │  ├─ 0.011 CalcVolumeForceForElems
   │     │  │  ├─ 0.002 CalcHourglassControlForElems
   │     │  │  │  └─ 0.003 CalcFBHourglassForceForElems
   │     │  │  └─ 0.005 IntegrateStressForElems
   │     │  ├─ 0.000 MPI_Irecv ▶
   │     │  ├─ 0.000 MPI_Isend ▶
   │     │  ├─ 0.000 MPI_Wait ▶
   │     │  └─ 0.000 MPI_Waitall ▶
   │     ├─ 0.000 MPI_Irecv ▶
   │     ├─ 0.000 MPI_Isend ▶
   │     ├─ 0.000 MPI_Wait ▶
   │     └─ 0.000 MPI_Waitall ▶
   └─ 0.018 TimeIncrement
      └─ 0.000 MPI_Allreduce

Legend (Metric: time)
🟩 0.03 - 0.04
🟩 0.03 - 0.03
🟩 0.02 - 0.03
🟨 0.01 - 0.02
🟧 0.00 - 0.01
🟥 0.00 - 0.00

name User code    ◀ Only in left graph    ▶ Only in right graph
```

3.3.2 Analyzing weak scaling performance

Hatchet can be used for comparing parallel scaling performance of applications. In this example, we compare the performance of LULESH running on 1 and 27 cores. By executing a simple `divide` of the two datasets in Hatchet, we can quickly identify which function calls did or did not scale well. In the resulting graph, we invert the color scheme, so that functions that did not scale well (i.e., have a low speedup) are colored in red.

```
gf_1core = ht.GraphFrame.from_caliper('lulesh*-1core.json')
gf_27cores = ht.GraphFrame.from_caliper('lulesh*-27cores.json')

gf_weak_scale = gf_1core / gf_27cores
```



```
59923.000 main
├─ 75.000 MPI_Barrier
├─ 8.000 MPI_Finalize
├─ 41.000 MPI_Reduce
└─ 1460.000 lulesh.cycle
   ├─ 892.000 LagrangeLeapFrog
   │  ├─ 3811.000 CalcTimeConstraintsForElems
   │  │  ├─ 110792.000 CalcCourantConstraintForElems
   │  │  └─ 25759.000 CalcHydroConstraintForElems
   │  ├─ 1328.000 LagrangeElements
   │  │  ├─ 76882.000 ApplyMaterialPropertiesForElems
   │  │  │  └─ 1723555.000 EvalEOSForElems
   │  │  │     ├─ 1823877.000 CalcEnergyForElems
   │  │  │     │  └─ 1512447.000 CalcPressureForElems
   │  │  │     └─ 71141.000 CalcSoundSpeedForElems
   │  │  ├─ 197762.000 CalcLagrangeElements
   │  │  │  └─ 3160618.000 CalcKinematicsForElems
   │  │  ├─ 212834.000 CalcQForElems
   │  │  │  ├─ 1379143.000 CalcMonotonicQGradientsForElems
   │  │  │  └─ 896384.000 CalcMonotonicQRegionForElems
   │  │  └─ 26698.000 UpdateVolumesForElems
   │  └─ 333306.000 LagrangeNodal
   │     └─ 117149.000 CalcForceForNodes
   │        └─ 118224.000 CalcVolumeForceForElems
   │           ├─ 8523384.000 CalcHourglassControlForElems
   │           │  └─ 3832556.000 CalcFBHourglassForceForElems
   │           └─ 3127526.000 IntegrateStressForElems
   └─ 673.000 TimeIncrement
      └─ 1481.000 MPI_Allreduce

Legend (Metric: time)
🟥 7671045.60 - 8523384.00
🟧 5966368.80 - 7671045.60
🟨 4261692.00 - 5966368.80
🟩 2557015.20 - 4261692.00
🟩 852338.40 - 2557015.20
🟩 0.00 - 852338.40

name User code    ◀ Only in left graph    ▶ Only in right graph
```

/

```
83309.000 main
├─ 618.000 MPI_Barrier
├─ 12.000 MPI_Finalize
├─ 53.000 MPI_Irecv
├─ 483.000 MPI_Isend
├─ 101777.000 MPI_Reduce
├─ 149.000 MPI_Wait
├─ 693.000 MPI_Waitall
└─ 1758.000 lulesh.cycle
   ├─ 1013.000 LagrangeLeapFrog
   │  ├─ 4636.000 CalcTimeConstraintsForElems
   │  │  ├─ 154884.000 CalcCourantConstraintForElems
   │  │  └─ 31661.000 CalcHydroConstraintForElems
   │  ├─ 2757.000 LagrangeElements
   │  │  ├─ 108863.000 ApplyMaterialPropertiesForElems
   │  │  │  └─ 2705741.000 EvalEOSForElems
   │  │  │     ├─ 2310052.000 CalcEnergyForElems
   │  │  │     │  └─ 1838144.000 CalcPressureForElems
   │  │  │     └─ 91071.000 CalcSoundSpeedForElems
   │  │  ├─ 308613.000 CalcLagrangeElements
   │  │  │  └─ 4009635.000 CalcKinematicsForElems
   │  │  ├─ 546900.000 CalcQForElems
   │  │  │  ├─ 1811567.000 CalcMonotonicQGradientsForElems
   │  │  │  ├─ 1375941.000 CalcMonotonicQRegionForElems
   │  │  │  ├─ 3033.000 MPI_Irecv
   │  │  │  ├─ 1744.000 MPI_Isend
   │  │  │  ├─ 53899.000 MPI_Wait
   │  │  │  └─ 1709258.000 MPI_Waitall
   │  │  └─ 45841.000 UpdateVolumesForElems
   │  └─ 1366962.000 LagrangeNodal
   │     ├─ 325670.000 CalcForceForNodes
   │     │  ├─ 450661.000 CalcVolumeForceForElems
   │     │  │  ├─ 12790409.000 CalcHourglassControlForElems
   │     │  │  │  └─ 4842004.000 CalcFBHourglassForceForElems
   │     │  │  └─ 3959205.000 IntegrateStressForElems
   │     │  ├─ 1811.000 MPI_Irecv
   │     │  ├─ 4339.000 MPI_Isend
   │     │  ├─ 31048.000 MPI_Wait
   │     │  └─ 85774.000 MPI_Waitall
   │     ├─ 1524.000 MPI_Irecv
   │     ├─ 0.000 MPI_Isend
   │     ├─ 428842.000 MPI_Wait
   │     └─ 1512.000 MPI_Waitall
   └─ 1183.000 TimeIncrement
      └─ 9310732.000 MPI_Allreduce

Legend (Metric: time)
🟥 11511368.10 - 12790409.00
🟧 8953286.30 - 11511368.10
🟨 6395204.50 - 8953286.30
🟩 3837122.70 - 6395204.50
🟩 1279040.90 - 3837122.70
🟩 0.00 - 1279040.90

name User code    ◀ Only in left graph    ▶ Only in right graph
```

```
0.719 main
├─ 0.121 MPI_Barrier
├─ 0.667 MPI_Finalize
├─ 0.000 MPI_Irecv ▶
├─ 0.000 MPI_Isend ▶
├─ 0.000 MPI_Reduce
├─ 0.000 MPI_Wait ▶
├─ 0.000 MPI_Waitall ▶
└─ 0.830 lulesh.cycle
   ├─ 0.881 LagrangeLeapFrog
   │  ├─ 0.822 CalcTimeConstraintsForElems
   │  │  ├─ 0.715 CalcCourantConstraintForElems
   │  │  └─ 0.814 CalcHydroConstraintForElems
   │  ├─ 0.482 LagrangeElements
   │  │  ├─ 0.706 ApplyMaterialPropertiesForElems
   │  │  │  └─ 0.637 EvalEOSForElems
   │  │  │     ├─ 0.790 CalcEnergyForElems
   │  │  │     │  └─ 0.823 CalcPressureForElems
   │  │  │     └─ 0.781 CalcSoundSpeedForElems
   │  │  ├─ 0.641 CalcLagrangeElements
   │  │  │  └─ 0.788 CalcKinematicsForElems
   │  │  ├─ 0.389 CalcQForElems
   │  │  │  ├─ 0.761 CalcMonotonicQGradientsForElems
   │  │  │  ├─ 0.651 CalcMonotonicQRegionForElems
   │  │  │  ├─ 0.000 MPI_Irecv ▶
   │  │  │  ├─ 0.000 MPI_Isend ▶
   │  │  │  ├─ 0.000 MPI_Wait ▶
   │  │  │  └─ 0.000 MPI_Waitall ▶
   │  │  └─ 0.582 UpdateVolumesForElems
   │  └─ 0.244 LagrangeNodal
   │     ├─ 0.360 CalcForceForNodes
   │     │  ├─ 0.262 CalcVolumeForceForElems
   │     │  │  ├─ 0.666 CalcHourglassControlForElems
   │     │  │  │  └─ 0.792 CalcFBHourglassForceForElems
   │     │  │  └─ 0.790 IntegrateStressForElems
   │     │  ├─ 0.000 MPI_Irecv ▶
   │     │  ├─ 0.000 MPI_Isend ▶
   │     │  ├─ 0.000 MPI_Wait ▶
   │     │  └─ 0.000 MPI_Waitall ▶
   │     ├─ 0.000 MPI_Irecv ▶
   │     ├─ 0.000 MPI_Isend ▶
   │     ├─ 0.000 MPI_Wait ▶
   │     └─ 0.000 MPI_Waitall ▶
   └─ 0.569 TimeIncrement
      └─ 0.000 MPI_Allreduce

Legend (Metric: time)
🟩 0.79 - 0.88
🟩 0.62 - 0.79
🟩 0.44 - 0.62
🟨 0.26 - 0.44
🟧 0.09 - 0.26
🟥 0.00 - 0.09

name User code    ◀ Only in left graph    ▶ Only in right graph
```

=

3.3.3 Identifying scaling bottlenecks

Hatchet can also be used to analyze data in a weak or strong scaling performance study. In this example, we ran LULESH from 1 to 512 cores on third powers of some numbers. We read in all the datasets into Hatchet, and for each dataset, we use a few lines of code to filter the regions where the code spends most of the time. We then use the pandas' pivot and plot operations to generate a stacked bar chart that shows how the time spent in different regions of LULESH changes as the code scales.

```python
# Grab all LULESH Caliper datasets, store in a sorted list.
datasets = glob.glob('lulesh*.json')
datasets.sort()

# For each dataset, create a new GraphFrame, and drop all index levels,
# except ``node``. Insert filtered graphframe into a list.
dataframes = []
for dataset in datasets:
    gf = ht.GraphFrame.from_caliper(dataset)
    gf.drop_index_levels()

    # Grab the number of processes from the file name, store this as a new
    # column in the DataFrame.
    num_pes = re.match('(.*)-(\d+)(.*)', dataset).group(2)
    gf.dataframe['pes'] = num_pes

    # Filter the GraphFrame keeping only those rows with ``time`` greater
    # than 1e6.
    filtered_gf = gf.filter(lambda x: x['time'] > 1e6)

    # Insert the filtered GraphFrame into a list.
```

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```
    dataframes.append(filtered_gf.dataframe)

# Concatenate all DataFrames into a single DataFrame called ``result``.
result = pd.concat(dataframes)

# Reshape the Dataframe, such that ``pes`` is an index column, ``name``
# fields are the new column names, and the values for each cell is the
# ``time`` fields.
pivot_df = result.pivot(index='pes', columns='name', values='time')

# Make a stacked bar chart using the data in the pivot table above.
pivot_df.loc[:,:].plot.bar(stacked=True, figsize=(10,7))
```

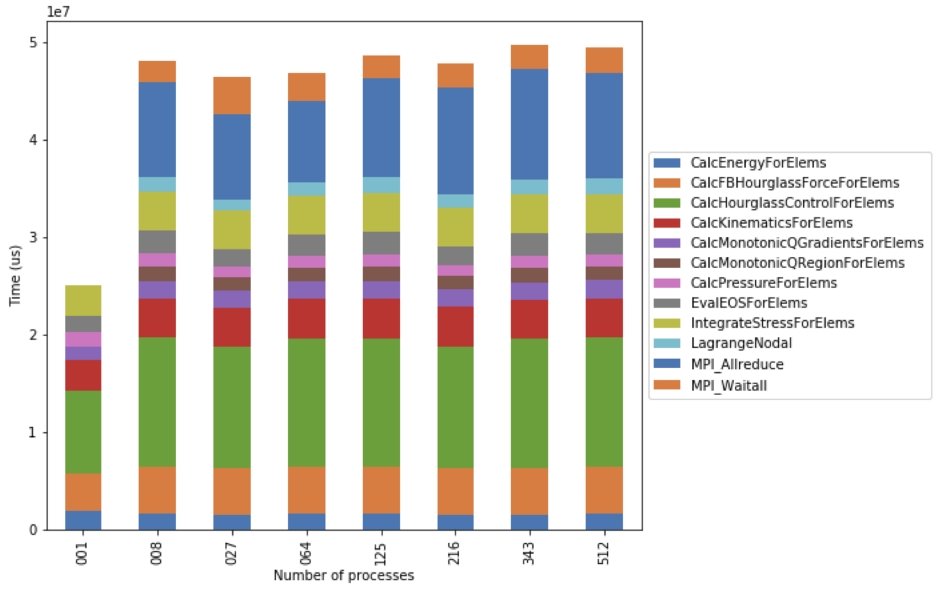

Fig. 5: Figure 5: Resulting stacked bar chart showing the time spent in different functions in LULESH as the code scales from 1 up to 512 processes. In this example, the `CalcHourglassControlForElems` function increases in runtime moving from 1 to 8 processes, then stays constant.

We use the same LULESH scaling datasets above to filter for time-consuming functions that start with the string `Calc`. This data is used to produce a line chart showing the performance of each function as the number of processes is increased. One of the functions (`CalcMonotonicQRegionForElems`) does not occur until the number of processes is greater than 1.

```
datasets = glob.glob('lulesh*.json')
datasets.sort()

dataframes = []
for dataset in datasets:
    gf = ht.GraphFrame.from_caliper(dataset)
    gf.drop_index_levels()

    num_pes = re.match('(.*)-(\d+)(.*)', dataset).group(2)
    gf.dataframe['pes'] = num_pes
    filtered_gf = gf.filter(lambda x: x["time"] > 1e6 and x["name"].startswith('Calc
↪'))
```

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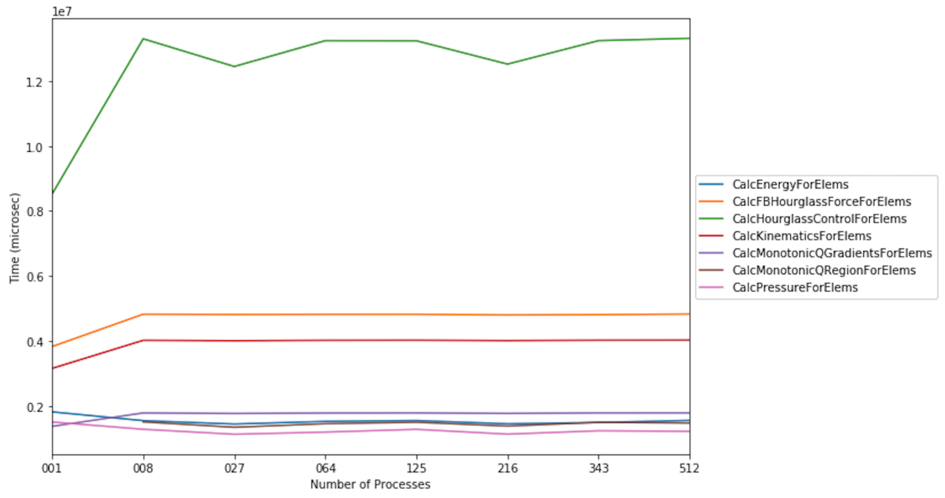
```
    dataframes.append(filtered_gf.dataframe)

result = pd.concat(dataframes)
pivot_df = result.pivot(index='pes', columns='name', values='time')
pivot_df.loc[:,:].plot.line(figsize=(10, 7))
```



If you encounter bugs while using hatchet, you can report them by opening an issue on GitHub.

If you are referencing hatchet in a publication, please cite the following paper:

- Abhinav Bhatele, Stephanie Brink, and Todd Gamblin. Hatchet: Pruning the Overgrowth in Parallel Profiles. In Proceedings of the International Conference for High Performance Computing, Networking, Storage and Analysis (SC ‘19). ACM, New York, NY, USA. DOI

CHAPTER 4

Basic Tutorial: Hatchet 101

This tutorial introduces how to use hatchet, including basics about:

- Installing hatchet
- Using the pandas API
- Using the hatchet API

4.1 Installing Hatchet and Tutorial Setup

You can install hatchet using pip:

```
$ pip install hatchet
```

After installing hatchet, you can import hatchet when running the Python interpreter in interactive mode:

```
$ python
Python 3.7.7 (default, Mar 14 2020, 02:39:01)
[Clang 10.0.1 (clang-1001.0.46.4)] on darwin
Type "help", "copyright", "credits" or "license" for more information.
>>>
```

Typing `import hatchet` at the prompt should succeed without any error messages:

```
>>> import hatchet as ht
>>>
```

You are good to go!

The Hatchet repository includes stand-alone Python-based Jupyter notebook examples based on this tutorial. You can find them in the hatchet GitHub repository. You can get a local copy of the repository using `git`:

```
$ git clone https://github.com/LLNL/hatchet.git
```

You will find the tutorial notebooks in your local hatchet repository under `docs/examples/tutorial/`.

4.2 Introduction

You can read in a dataset into Hatchet for analysis by using one of several `from_` static methods. For example, you can read in a Caliper JSON file as follows:

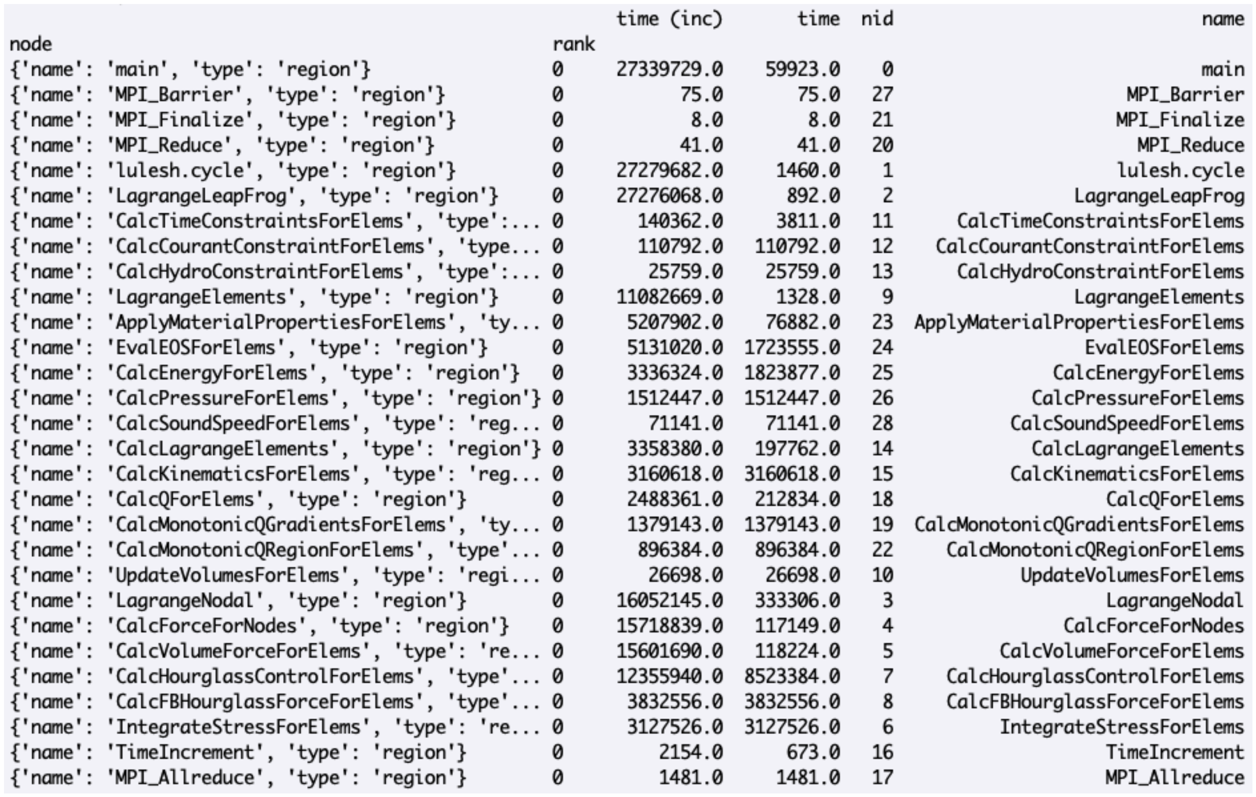
```
>>> import hatchet as ht
>>> caliper_file = 'lulesh-annotation-profile-1core.json'
>>> gf = ht.GraphFrame.from_caliper_json(caliper_file)
>>>
```

At this point, your input file (profile) has been loaded into Hatchet's data structure, known as a GraphFrame. Hatchet's GraphFrame contains a pandas DataFrame and a corresponding graph.

The DataFrame component of Hatchet's GraphFrame contains the metrics and other non-numeric data associated with each node in the dataset. You can print the dataframe by typing:

```
>>> print(gf.dataframe)
```

This should produce output like this:

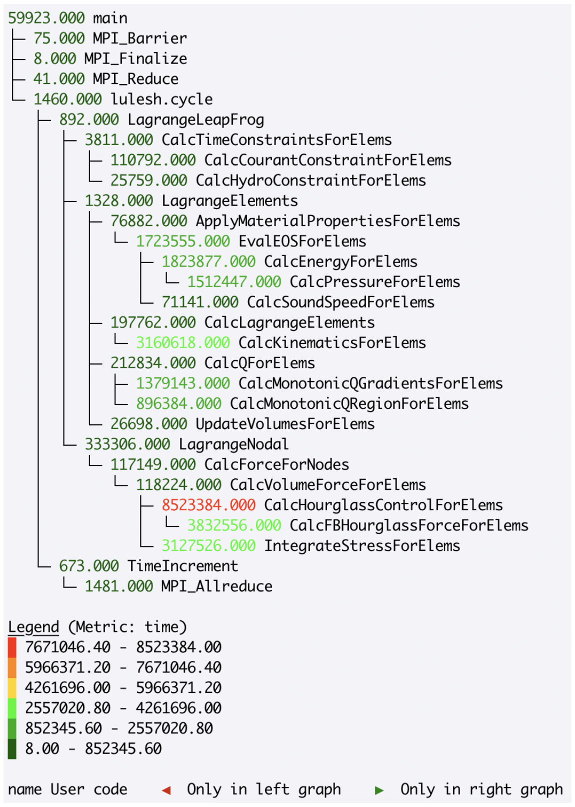


```
                                                       time (inc)       time  nid                             name
node                                             rank
{'name': 'main', 'type': 'region'}               0     27339729.0    59923.0    0                             main
{'name': 'MPI_Barrier', 'type': 'region'}        0           75.0       75.0   27                      MPI_Barrier
{'name': 'MPI_Finalize', 'type': 'region'}       0            8.0        8.0   21                     MPI_Finalize
{'name': 'MPI_Reduce', 'type': 'region'}         0           41.0       41.0   20                       MPI_Reduce
{'name': 'lulesh.cycle', 'type': 'region'}       0     27279682.0     1460.0    1                     lulesh.cycle
{'name': 'LagrangeLeapFrog', 'type': 'region'}   0     27276068.0      892.0    2                 LagrangeLeapFrog
{'name': 'CalcTimeConstraintsForElems', 'type':... 0     140362.0     3811.0   11      CalcTimeConstraintsForElems
{'name': 'CalcCourantConstraintForElems', 'type... 0     110792.0   110792.0   12    CalcCourantConstraintForElems
{'name': 'CalcHydroConstraintForElems', 'type':... 0      25759.0    25759.0   13      CalcHydroConstraintForElems
{'name': 'LagrangeElements', 'type': 'region'}   0     11082669.0     1328.0    9                 LagrangeElements
{'name': 'ApplyMaterialPropertiesForElems', 'ty... 0    5207902.0    76882.0   23  ApplyMaterialPropertiesForElems
{'name': 'EvalEOSForElems', 'type': 'region'}    0      5131020.0  1723555.0   24                  EvalEOSForElems
{'name': 'CalcEnergyForElems', 'type': 'region'} 0      3336324.0  1823877.0   25               CalcEnergyForElems
{'name': 'CalcPressureForElems', 'type': 'region'} 0    1512447.0  1512447.0   26             CalcPressureForElems
{'name': 'CalcSoundSpeedForElems', 'type': 'reg... 0      71141.0    71141.0   28           CalcSoundSpeedForElems
{'name': 'CalcLagrangeElements', 'type': 'region'} 0    3358380.0   197762.0   14             CalcLagrangeElements
{'name': 'CalcKinematicsForElems', 'type': 'reg... 0    3160618.0  3160618.0   15           CalcKinematicsForElems
{'name': 'CalcQForElems', 'type': 'region'}      0      2488361.0   212834.0   18                    CalcQForElems
{'name': 'CalcMonotonicQGradientsForElems', 'ty... 0    1379143.0  1379143.0   19  CalcMonotonicQGradientsForElems
{'name': 'CalcMonotonicQRegionForElems', 'type'... 0     896384.0   896384.0   22     CalcMonotonicQRegionForElems
{'name': 'UpdateVolumesForElems', 'type': 'regi... 0      26698.0    26698.0   10            UpdateVolumesForElems
{'name': 'LagrangeNodal', 'type': 'region'}      0     16052145.0   333306.0    3                    LagrangeNodal
{'name': 'CalcForceForNodes', 'type': 'region'}  0     15718839.0   117149.0    4                CalcForceForNodes
{'name': 'CalcVolumeForceForElems', 'type': 're... 0   15601690.0   118224.0    5          CalcVolumeForceForElems
{'name': 'CalcHourglassControlForElems', 'type'... 0   12355940.0  8523384.0    7     CalcHourglassControlForElems
{'name': 'CalcFBHourglassForceForElems', 'type'... 0    3832556.0  3832556.0    8     CalcFBHourglassForceForElems
{'name': 'IntegrateStressForElems', 'type': 're... 0    3127526.0  3127526.0    6          IntegrateStressForElems
{'name': 'TimeIncrement', 'type': 'region'}      0         2154.0      673.0   16                    TimeIncrement
{'name': 'MPI_Allreduce', 'type': 'region'}      0         1481.0     1481.0   17                    MPI_Allreduce
```

The Graph component of Hatchet's GraphFrame stores the connections between parents and children. You can print the graph using hatchet's tree printing functionality:

```
>>> print(gf.tree())
```

This will print a graphical version of the tree to the terminal:



```
59923.000 main
├─ 75.000 MPI_Barrier
├─ 8.000 MPI_Finalize
├─ 41.000 MPI_Reduce
└─ 1460.000 lulesh.cycle
   ├─ 892.000 LagrangeLeapFrog
   │  ├─ 3811.000 CalcTimeConstraintsForElems
   │  │  ├─ 110792.000 CalcCourantConstraintForElems
   │  │  └─ 25759.000 CalcHydroConstraintForElems
   │  ├─ 1328.000 LagrangeElements
   │  │  ├─ 76882.000 ApplyMaterialPropertiesForElems
   │  │  │  └─ 1723555.000 EvalEOSForElems
   │  │  │     ├─ 1823877.000 CalcEnergyForElems
   │  │  │     │  └─ 1512447.000 CalcPressureForElems
   │  │  │     └─ 71141.000 CalcSoundSpeedForElems
   │  │  ├─ 197762.000 CalcLagrangeElements
   │  │  │  └─ 3160618.000 CalcKinematicsForElems
   │  │  ├─ 212834.000 CalcQForElems
   │  │  │  ├─ 1379143.000 CalcMonotonicQGradientsForElems
   │  │  │  └─ 896384.000 CalcMonotonicQRegionForElems
   │  │  └─ 26698.000 UpdateVolumesForElems
   │  └─ 333306.000 LagrangeNodal
   │     └─ 117149.000 CalcForceForNodes
   │        └─ 118224.000 CalcVolumeForceForElems
   │           ├─ 8523384.000 CalcHourglassControlForElems
   │           │  └─ 3832556.000 CalcFBHourglassForceForElems
   │           └─ 3127526.000 IntegrateStressForElems
   └─ 673.000 TimeIncrement
      └─ 1481.000 MPI_Allreduce

Legend (Metric: time)
🟥 7671046.40 - 8523384.00
🟧 5966371.20 - 7671046.40
🟨 4261696.00 - 5966371.20
🟩 2557020.80 - 4261696.00
🟩 852345.60 - 2557020.80
🟩 8.00 - 852345.60

name User code    ◀ Only in left graph    ▶ Only in right graph
```

4.3 Analyzing the DataFrame using pandas

The `DataFrame` is one of two components that makeup the `GraphFrame` in hatchet. The pandas `DataFrame` stores the performance metrics and other non-numeric data for all nodes in the graph.

You can apply any pandas operations to the dataframe in hatchet. Note that modifying the dataframe in hatchet outside of the hatchet API is not recommended because operations that modify the dataframe can make the dataframe and graph inconsistent.

By default, the rows in the dataframe are sorted in traversal order. Sorting the rows by a different column can be done as follows:

```
>>> sorted_df = gf.dataframe.sort_values(by=['time'], ascending=False)
```

Individual numeric columns in the dataframe can be scaled or offset by a constant using native pandas operations. In the following example, we add a new column called `scale` to the existing dataframe, and print the dataframe sorted by this new column from lowest to highest:

```
>>> gf.dataframe['scale'] = gf.dataframe['time'] * 4
>>> sorted_df = gf.dataframe.sort_values(by=['scale'], ascending=True)
```

4.4 Analyzing the Graph via printing

Hatchet provides several methods of visualizing graphs. In this section, we show how a user can use the `tree()` method to convert the graph to a string that can be displayed to standard output. This function has several different parameters that can alter the output. To look at all the available parameters, you can look at the docstrings as follows:

```
                                                      time (inc)       time  nid                             name
node                                               rank
{'name': 'CalcHourglassControlForElems', 'type'... 0   12355940.0  8523384.0    7     CalcHourglassControlForElems
{'name': 'CalcFBHourglassForceForElems', 'type'... 0    3832556.0  3832556.0    8     CalcFBHourglassForceForElems
{'name': 'CalcKinematicsForElems', 'type': 'reg... 0    3160618.0  3160618.0   15           CalcKinematicsForElems
{'name': 'IntegrateStressForElems', 'type': 're... 0    3127526.0  3127526.0    6          IntegrateStressForElems
{'name': 'CalcEnergyForElems', 'type': 'region'}   0    3336324.0  1823877.0   25               CalcEnergyForElems
{'name': 'EvalEOSForElems', 'type': 'region'}      0    5131020.0  1723555.0   24                  EvalEOSForElems
{'name': 'CalcPressureForElems', 'type': 'region'} 0    1512447.0  1512447.0   26             CalcPressureForElems
{'name': 'CalcMonotonicQGradientsForElems', 'ty... 0    1379143.0  1379143.0   19  CalcMonotonicQGradientsForElems
{'name': 'CalcMonotonicQRegionForElems', 'type'... 0     896384.0   896384.0   22     CalcMonotonicQRegionForElems
{'name': 'LagrangeNodal', 'type': 'region'}        0   16052145.0   333306.0    3                    LagrangeNodal
{'name': 'CalcQForElems', 'type': 'region'}        0    2488361.0   212834.0   18                    CalcQForElems
{'name': 'CalcLagrangeElements', 'type': 'region'} 0    3358380.0   197762.0   14             CalcLagrangeElements
{'name': 'CalcVolumeForceForElems', 'type': 're... 0   15601690.0   118224.0    5          CalcVolumeForceForElems
{'name': 'CalcForceForNodes', 'type': 'region'}    0   15718839.0   117149.0    4                CalcForceForNodes
{'name': 'CalcCourantConstraintForElems', 'type... 0     110792.0   110792.0   12    CalcCourantConstraintForElems
{'name': 'ApplyMaterialPropertiesForElems', 'ty... 0    5207902.0    76882.0   23  ApplyMaterialPropertiesForElems
{'name': 'CalcSoundSpeedForElems', 'type': 'reg... 0      71141.0    71141.0   28           CalcSoundSpeedForElems
{'name': 'main', 'type': 'region'}                 0   27339729.0    59923.0    0                             main
{'name': 'UpdateVolumesForElems', 'type': 'regi... 0      26698.0    26698.0   10            UpdateVolumesForElems
{'name': 'CalcHydroConstraintForElems', 'type':... 0      25759.0    25759.0   13      CalcHydroConstraintForElems
{'name': 'CalcTimeConstraintsForElems', 'type':... 0     140362.0     3811.0   11      CalcTimeConstraintsForElems
{'name': 'MPI_Allreduce', 'type': 'region'}        0       1481.0     1481.0   17                    MPI_Allreduce
{'name': 'lulesh.cycle', 'type': 'region'}         0   27279682.0     1460.0    1                     lulesh.cycle
{'name': 'LagrangeElements', 'type': 'region'}     0   11082669.0     1328.0    9                 LagrangeElements
{'name': 'LagrangeLeapFrog', 'type': 'region'}     0   27276068.0      892.0    2                 LagrangeLeapFrog
{'name': 'TimeIncrement', 'type': 'region'}        0       2154.0      673.0   16                    TimeIncrement
{'name': 'MPI_Barrier', 'type': 'region'}          0         75.0       75.0   27                      MPI_Barrier
{'name': 'MPI_Reduce', 'type': 'region'}           0         41.0       41.0   20                       MPI_Reduce
{'name': 'MPI_Finalize', 'type': 'region'}         0          8.0        8.0   21                     MPI_Finalize
```

```
                                                      time (inc)       time  nid                             name       scale
node                                               rank
{'name': 'MPI_Finalize', 'type': 'region'}         0          8.0        8.0   21                     MPI_Finalize        32.0
{'name': 'MPI_Reduce', 'type': 'region'}           0         41.0       41.0   20                       MPI_Reduce       164.0
{'name': 'MPI_Barrier', 'type': 'region'}          0         75.0       75.0   27                      MPI_Barrier       300.0
{'name': 'TimeIncrement', 'type': 'region'}        0       2154.0      673.0   16                    TimeIncrement      2692.0
{'name': 'LagrangeLeapFrog', 'type': 'region'}     0   27276068.0      892.0    2                 LagrangeLeapFrog      3568.0
{'name': 'LagrangeElements', 'type': 'region'}     0   11082669.0     1328.0    9                 LagrangeElements      5312.0
{'name': 'lulesh.cycle', 'type': 'region'}         0   27279682.0     1460.0    1                     lulesh.cycle      5840.0
{'name': 'MPI_Allreduce', 'type': 'region'}        0       1481.0     1481.0   17                    MPI_Allreduce      5924.0
{'name': 'CalcTimeConstraintsForElems', 'type':... 0     140362.0     3811.0   11      CalcTimeConstraintsForElems     15244.0
{'name': 'CalcHydroConstraintForElems', 'type':... 0      25759.0    25759.0   13      CalcHydroConstraintForElems    103036.0
{'name': 'UpdateVolumesForElems', 'type': 'regi... 0      26698.0    26698.0   10            UpdateVolumesForElems    106792.0
{'name': 'main', 'type': 'region'}                 0   27339729.0    59923.0    0                             main    239692.0
{'name': 'CalcSoundSpeedForElems', 'type': 'reg... 0      71141.0    71141.0   28           CalcSoundSpeedForElems    284564.0
{'name': 'ApplyMaterialPropertiesForElems', 'ty... 0    5207902.0    76882.0   23  ApplyMaterialPropertiesForElems    307528.0
{'name': 'CalcCourantConstraintForElems', 'type... 0     110792.0   110792.0   12    CalcCourantConstraintForElems    443168.0
{'name': 'CalcForceForNodes', 'type': 'region'}    0   15718839.0   117149.0    4                CalcForceForNodes    468596.0
{'name': 'CalcVolumeForceForElems', 'type': 're... 0   15601690.0   118224.0    5          CalcVolumeForceForElems    472896.0
{'name': 'CalcLagrangeElements', 'type': 'region'} 0    3358380.0   197762.0   14             CalcLagrangeElements    791048.0
{'name': 'CalcQForElems', 'type': 'region'}        0    2488361.0   212834.0   18                    CalcQForElems    851336.0
{'name': 'LagrangeNodal', 'type': 'region'}        0   16052145.0   333306.0    3                    LagrangeNodal   1333224.0
{'name': 'CalcMonotonicQRegionForElems', 'type'... 0     896384.0   896384.0   22     CalcMonotonicQRegionForElems   3585536.0
{'name': 'CalcMonotonicQGradientsForElems', 'ty... 0    1379143.0  1379143.0   19  CalcMonotonicQGradientsForElems   5516572.0
{'name': 'CalcPressureForElems', 'type': 'region'} 0    1512447.0  1512447.0   26             CalcPressureForElems   6049788.0
{'name': 'EvalEOSForElems', 'type': 'region'}      0    5131020.0  1723555.0   24                  EvalEOSForElems   6894220.0
{'name': 'CalcEnergyForElems', 'type': 'region'}   0    3336324.0  1823877.0   25               CalcEnergyForElems   7295508.0
{'name': 'IntegrateStressForElems', 'type': 're... 0    3127526.0  3127526.0    6          IntegrateStressForElems  12510104.0
{'name': 'CalcKinematicsForElems', 'type': 'reg... 0    3160618.0  3160618.0   15           CalcKinematicsForElems  12642472.0
{'name': 'CalcFBHourglassForceForElems', 'type'... 0    3832556.0  3832556.0    8     CalcFBHourglassForceForElems  15330224.0
{'name': 'CalcHourglassControlForElems', 'type'... 0   12355940.0  8523384.0    7     CalcHourglassControlForElems  34093536.0
```

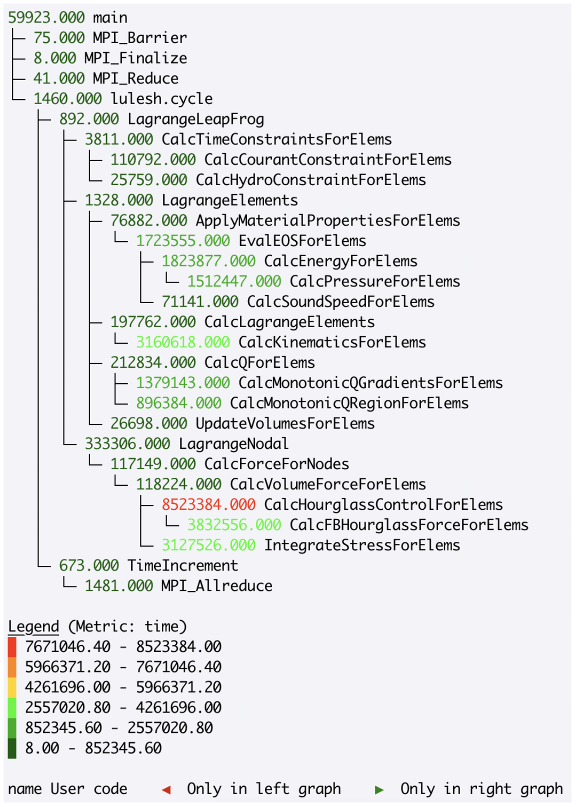
```
>>> help(gf.tree)

Help on method tree in module hatchet.graphframe:

tree(metric_column='time', precision=3, name_column='name', expand_name=False,
context_column='file', rank=0, thread=0, depth=10000, highlight_name=False,
invert_colormap=False) method of hatchet.graphframe.GraphFrame instance
    Format this graphframe as a tree and return the resulting string.
```

To print the graph output:

```
>>> gf.tree()
```



```
59923.000 main
├─ 75.000 MPI_Barrier
├─ 8.000 MPI_Finalize
├─ 41.000 MPI_Reduce
└─ 1460.000 lulesh.cycle
   ├─ 892.000 LagrangeLeapFrog
   │  ├─ 3811.000 CalcTimeConstraintsForElems
   │  │  ├─ 110792.000 CalcCourantConstraintForElems
   │  │  └─ 25759.000 CalcHydroConstraintForElems
   │  ├─ 1328.000 LagrangeElements
   │  │  ├─ 76882.000 ApplyMaterialPropertiesForElems
   │  │  │  └─ 1723555.000 EvalEOSForElems
   │  │  │     ├─ 1823877.000 CalcEnergyForElems
   │  │  │     │  └─ 1512447.000 CalcPressureForElems
   │  │  │     └─ 71141.000 CalcSoundSpeedForElems
   │  │  ├─ 197762.000 CalcLagrangeElements
   │  │  │  └─ 3160618.000 CalcKinematicsForElems
   │  │  ├─ 212834.000 CalcQForElems
   │  │  │  ├─ 1379143.000 CalcMonotonicQGradientsForElems
   │  │  │  └─ 896384.000 CalcMonotonicQRegionForElems
   │  │  └─ 26698.000 UpdateVolumesForElems
   │  └─ 333306.000 LagrangeNodal
   │     └─ 117149.000 CalcForceForNodes
   │        └─ 118224.000 CalcVolumeForceForElems
   │           ├─ 8523384.000 CalcHourglassControlForElems
   │           │  └─ 3832556.000 CalcFBHourglassForceForElems
   │           └─ 3127526.000 IntegrateStressForElems
   └─ 673.000 TimeIncrement
      └─ 1481.000 MPI_Allreduce

Legend (Metric: time)
🟥 7671046.40 - 8523384.00
🟧 5966371.20 - 7671046.40
🟨 4261696.00 - 5966371.20
🟩 2557020.80 - 4261696.00
🟩 852345.60 - 2557020.80
🟩 8.00 - 852345.60

name User code    ◀ Only in left graph    ▶ Only in right graph
```

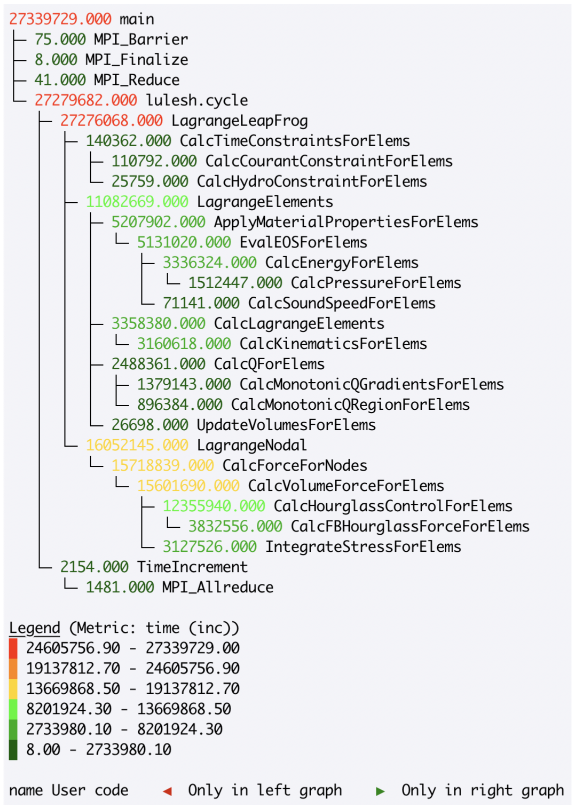
By default, the graph printout displays next to each node values in the `time` column of the dataframe. To display another column, change the argument to the `metric_column=` parameter:

```
>>> gf.tree(metric_column='time (inc)')
```

To view a subset of the nodes in the graph, a user can change the `depth=` value to indicate how many levels of the tree to display. By default, all levels in the tree are displayed. In the following example, we only ask to display the first three levels of the tree, where the root is the first level:

```
>>> gf.tree(depth=3)
```

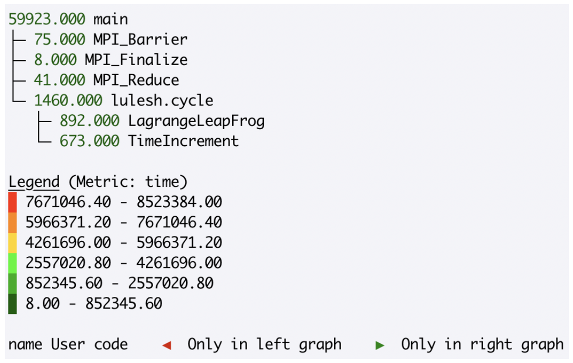
By default, the `tree()` method uses a red-green colormap, whereby nodes with high metric values are colored red, while nodes with low metric values are colored green. In some use cases, a user may want to reverse the colormap to draw attention to certain nodes, such as performing a division of two graphframes to compute speedup:



```
27339729.000 main
├─ 75.000 MPI_Barrier
├─ 8.000 MPI_Finalize
├─ 41.000 MPI_Reduce
└─ 27279682.000 lulesh.cycle
   ├─ 27276068.000 LagrangeLeapFrog
   │  ├─ 140362.000 CalcTimeConstraintsForElems
   │  │  ├─ 110792.000 CalcCourantConstraintForElems
   │  │  └─ 25759.000 CalcHydroConstraintForElems
   │  ├─ 11082669.000 LagrangeElements
   │  │  ├─ 5207902.000 ApplyMaterialPropertiesForElems
   │  │  │  └─ 5131020.000 EvalEOSForElems
   │  │  │     ├─ 3336324.000 CalcEnergyForElems
   │  │  │     │  └─ 1512447.000 CalcPressureForElems
   │  │  │     └─ 71141.000 CalcSoundSpeedForElems
   │  │  ├─ 3358380.000 CalcLagrangeElements
   │  │  │  └─ 3160618.000 CalcKinematicsForElems
   │  │  ├─ 2488361.000 CalcQForElems
   │  │  │  ├─ 1379143.000 CalcMonotonicQGradientsForElems
   │  │  │  └─ 896384.000 CalcMonotonicQRegionForElems
   │  │  └─ 26698.000 UpdateVolumesForElems
   │  └─ 16052145.000 LagrangeNodal
   │     └─ 15718839.000 CalcForceForNodes
   │        └─ 15601690.000 CalcVolumeForceForElems
   │           ├─ 12355940.000 CalcHourglassControlForElems
   │           │  └─ 3832556.000 CalcFBHourglassForceForElems
   │           └─ 3127526.000 IntegrateStressForElems
   └─ 2154.000 TimeIncrement
      └─ 1481.000 MPI_Allreduce

Legend (Metric: time (inc))
🟥 24605756.90 - 27339729.00
🟧 19137812.70 - 24605756.90
🟨 13669868.50 - 19137812.70
🟩 8201924.30 - 13669868.50
🟩 2733980.10 - 8201924.30
🟩 8.00 - 2733980.10

name User code    ◀  Only in left graph    ▶  Only in right graph
```

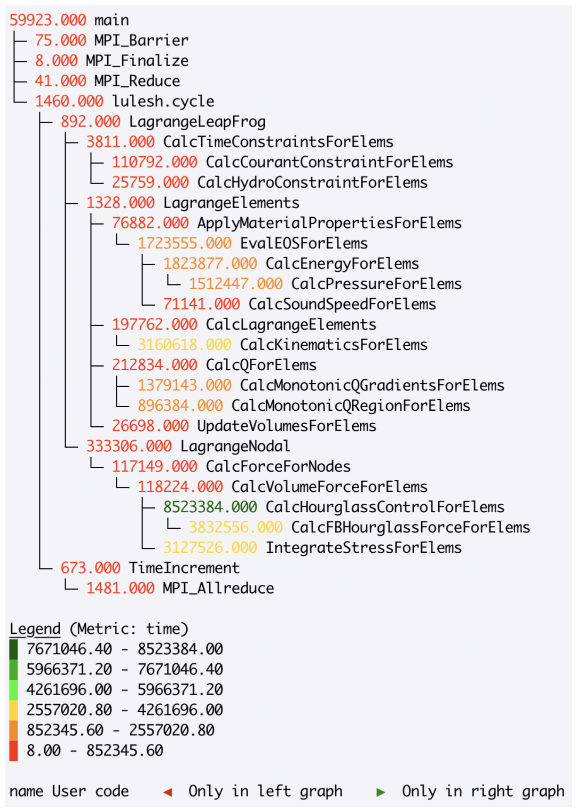


```
59923.000 main
├─ 75.000 MPI_Barrier
├─ 8.000 MPI_Finalize
├─ 41.000 MPI_Reduce
└─ 1460.000 lulesh.cycle
   ├─ 892.000 LagrangeLeapFrog
   └─ 673.000 TimeIncrement

Legend (Metric: time)
🟥 7671046.40 - 8523384.00
🟧 5966371.20 - 7671046.40
🟨 4261696.00 - 5966371.20
🟩 2557020.80 - 4261696.00
🟩 852345.60 - 2557020.80
🟩 8.00 - 852345.60

name User code    ◀  Only in left graph    ▶  Only in right graph
```

```
>>> gf.tree(invert_colormap=True)
```



```
59923.000 main
├─ 75.000 MPI_Barrier
├─ 8.000 MPI_Finalize
├─ 41.000 MPI_Reduce
└─ 1460.000 lulesh.cycle
   ├─ 892.000 LagrangeLeapFrog
   │  ├─ 3811.000 CalcTimeConstraintsForElems
   │  │  ├─ 110792.000 CalcCourantConstraintForElems
   │  │  └─ 25759.000 CalcHydroConstraintForElems
   │  ├─ 1328.000 LagrangeElements
   │  │  ├─ 76882.000 ApplyMaterialPropertiesForElems
   │  │  │  └─ 1723555.000 EvalEOSForElems
   │  │  │     ├─ 1823877.000 CalcEnergyForElems
   │  │  │     │  └─ 1512447.000 CalcPressureForElems
   │  │  │     └─ 71141.000 CalcSoundSpeedForElems
   │  │  ├─ 197762.000 CalcLagrangeElements
   │  │  │  └─ 3160618.000 CalcKinematicsForElems
   │  │  ├─ 212834.000 CalcQForElems
   │  │  │  ├─ 1379143.000 CalcMonotonicQGradientsForElems
   │  │  │  └─ 896384.000 CalcMonotonicQRegionForElems
   │  │  └─ 26698.000 UpdateVolumesForElems
   │  └─ 333306.000 LagrangeNodal
   │     └─ 117149.000 CalcForceForNodes
   │        └─ 118224.000 CalcVolumeForceForElems
   │           ├─ 8523384.000 CalcHourglassControlForElems
   │           │  └─ 3832556.000 CalcFBHourglassForceForElems
   │           └─ 3127526.000 IntegrateStressForElems
   └─ 673.000 TimeIncrement
      └─ 1481.000 MPI_Allreduce

Legend (Metric: time)
🟩 7671046.40 - 8523384.00
🟩 5966371.20 - 7671046.40
🟩 4261696.00 - 5966371.20
🟨 2557020.80 - 4261696.00
🟧 852345.60 - 2557020.80
🟥 8.00 - 852345.60

name User code    ◀ Only in left graph    ▶ Only in right graph
```

For a dataset that contains rank- and/or thread-level data, the tree visualization shows the metrics for rank 0 and thread 0 by default. To look at the metrics for a different rank or thread, a user can change the `rank=` or `thread=` parameters:

```
>>> gf.tree(rank=4)
```

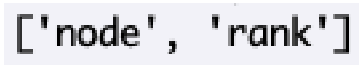
4.5 Analyzing the GraphFrame

Depending on the input data file, the DataFrame may be initialized with one or multiple index levels. In hatchet, the only required index level is `node`, but some readers may also set `rank` and `thread` as additional index levels. The index is a feature of pandas that is used to uniquely identify each row in the Dataframe.

We can query the column names of the index levels as follows:

```
>>> print(gf.dataframe.index.names)
```

This will show the column names of the index levels in a list:

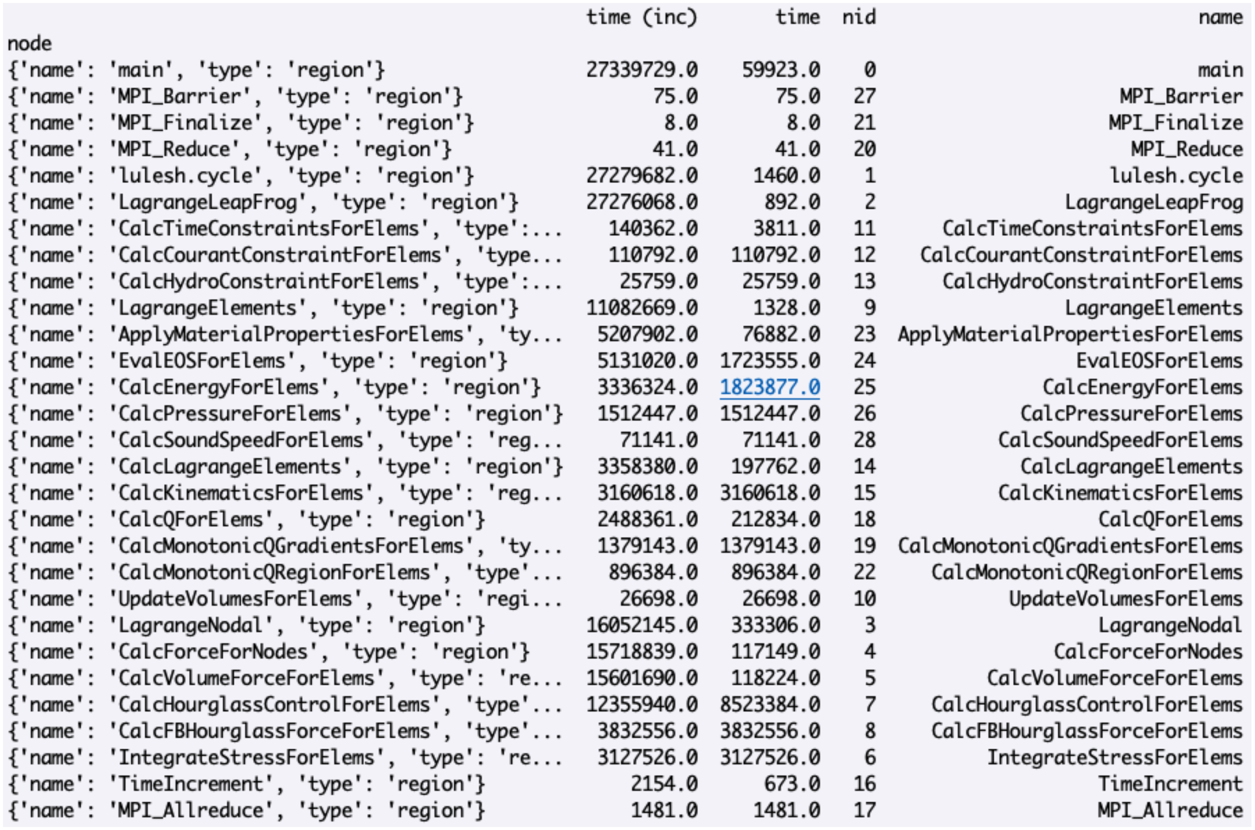


```
['node', 'rank']
```

For this dataset, we see that there are two index columns: `node` and `rank`. Since hatchet requires (at least) `node` to be an index level, we can drop the extra `rank` index level, which will aggregate the data over all MPI ranks at the per-node granularity.

```
>>> gf.drop_index_levels()
>>> print(gf.dataframe)
```

This will aggregate over all MPI ranks and drop all index levels (except `node`).

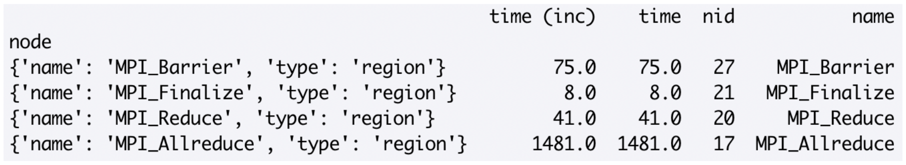


```
                                                 time (inc)       time  nid                              name
node
{'name': 'main', 'type': 'region'}                27339729.0    59923.0    0                              main
{'name': 'MPI_Barrier', 'type': 'region'}               75.0       75.0   27                       MPI_Barrier
{'name': 'MPI_Finalize', 'type': 'region'}               8.0        8.0   21                      MPI_Finalize
{'name': 'MPI_Reduce', 'type': 'region'}                41.0       41.0   20                        MPI_Reduce
{'name': 'lulesh.cycle', 'type': 'region'}        27279682.0     1460.0    1                      lulesh.cycle
{'name': 'LagrangeLeapFrog', 'type': 'region'}    27276068.0      892.0    2                  LagrangeLeapFrog
{'name': 'CalcTimeConstraintsForElems', 'type':...  140362.0     3811.0   11       CalcTimeConstraintsForElems
{'name': 'CalcCourantConstraintForElems', 'type...  110792.0   110792.0   12     CalcCourantConstraintForElems
{'name': 'CalcHydroConstraintForElems', 'type':...   25759.0    25759.0   13       CalcHydroConstraintForElems
{'name': 'LagrangeElements', 'type': 'region'}    11082669.0     1328.0    9                  LagrangeElements
{'name': 'ApplyMaterialPropertiesForElems', 'ty... 5207902.0    76882.0   23  ApplyMaterialPropertiesForElems
{'name': 'EvalEOSForElems', 'type': 'region'}      5131020.0  1723555.0   24                   EvalEOSForElems
{'name': 'CalcEnergyForElems', 'type': 'region'}   3336324.0  1823877.0   25                CalcEnergyForElems
{'name': 'CalcPressureForElems', 'type': 'region'} 1512447.0  1512447.0   26              CalcPressureForElems
{'name': 'CalcSoundSpeedForElems', 'type': 'reg...   71141.0    71141.0   28            CalcSoundSpeedForElems
{'name': 'CalcLagrangeElements', 'type': 'region'} 3358380.0   197762.0   14              CalcLagrangeElements
{'name': 'CalcKinematicsForElems', 'type': 'reg... 3160618.0  3160618.0   15            CalcKinematicsForElems
{'name': 'CalcQForElems', 'type': 'region'}        2488361.0   212834.0   18                     CalcQForElems
{'name': 'CalcMonotonicQGradientsForElems', 'ty... 1379143.0  1379143.0   19  CalcMonotonicQGradientsForElems
{'name': 'CalcMonotonicQRegionForElems', 'type'...  896384.0   896384.0   22     CalcMonotonicQRegionForElems
{'name': 'UpdateVolumesForElems', 'type': 'regi...   26698.0    26698.0   10             UpdateVolumesForElems
{'name': 'LagrangeNodal', 'type': 'region'}       16052145.0   333306.0    3                     LagrangeNodal
{'name': 'CalcForceForNodes', 'type': 'region'}   15718839.0   117149.0    4                 CalcForceForNodes
{'name': 'CalcVolumeForceForElems', 'type': 're... 15601690.0   118224.0    5           CalcVolumeForceForElems
{'name': 'CalcHourglassControlForElems', 'type'... 12355940.0  8523384.0    7      CalcHourglassControlForElems
{'name': 'CalcFBHourglassForceForElems', 'type'...  3832556.0  3832556.0    8      CalcFBHourglassForceForElems
{'name': 'IntegrateStressForElems', 'type': 're...  3127526.0  3127526.0    6           IntegrateStressForElems
{'name': 'TimeIncrement', 'type': 'region'}            2154.0      673.0   16                     TimeIncrement
{'name': 'MPI_Allreduce', 'type': 'region'}            1481.0     1481.0   17                     MPI_Allreduce
```

Now let's imagine we want to focus our analysis on a particular set of nodes. We can filter the GraphFrame by some user-supplied function, which will reduce the number of rows in the DataFrame as well as the number of nodes in the graph. For this example, let's say we are only interested in nodes that start with the name `MPI_`.

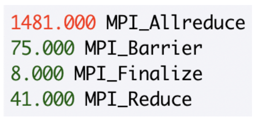
```
>>> filt_func = lambda x: x['name'].startswith('MPI_')
>>> filter_gf = gf.filter(filt_func, squash=True)
>>> print(filter_gf.dataframe)
```

This will show a dataframe only containing those nodes that start with `MPI_`:



```
                                             time (inc)    time  nid           name
node
{'name': 'MPI_Barrier', 'type': 'region'}          75.0    75.0   27    MPI_Barrier
{'name': 'MPI_Finalize', 'type': 'region'}          8.0     8.0   21   MPI_Finalize
{'name': 'MPI_Reduce', 'type': 'region'}           41.0    41.0   20     MPI_Reduce
{'name': 'MPI_Allreduce', 'type': 'region'}      1481.0  1481.0   17  MPI_Allreduce
```

By default, `filter` will make the graph consistent with the dataframe, so the dataframe and the graph contain the same number of nodes. That is, we specify `squash=True`, so the graph and the dataframe are inconsistent. When we print out the tree, we see that it has the same nodes as the filtered dataframe:



```
1481.000 MPI_Allreduce
75.000 MPI_Barrier
8.000 MPI_Finalize
41.000 MPI_Reduce
```

4.6 Analyzing Multiple GraphFrames

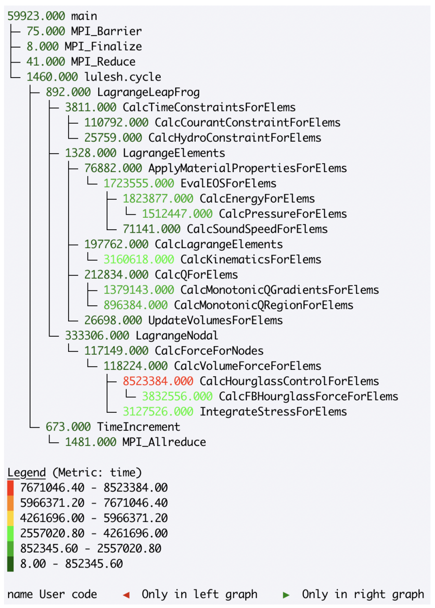
With hatchet, we can perform mathematical operators on multiple GraphFrames. This is useful for comparing the performance of functions at increasing concurrency or computing speedup of two different implementations of the same function, for example.

In the example below, we have two LULESH profiles collected at 1 and 64 cores using Caliper. The graphs of these two profiles are slightly different in structure. Due to the scale of the 64 core LULESH run, its profile contains additional MPI-related functions than the 1 core run. With hatchet, we can operate on profiles with different graph structures by first unifying the graphs, and the resulting graph annotates the nodes to indicate which graph the node originated from.

By dividing the profiles, we can analyze how the functions scale at higher concurrencies. Before performing the division operator, we drop the extra `rank` index level in both profiles, which aggregates the data over all MPI ranks at the per-node granularity. When printing the tree, we specify `invert_colormap=True`, so that nodes with good speedup (i.e., low values) are colored green, while nodes with poor speedup (i.e., high values) are colored red. By default, nodes with low values are colored green, while high values are colored red.

Additionally, because the 64 core profile contained more nodes than the 1 core profile, the resulting tree is annotated with green triangles pointing to the right, indicating that these nodes originally came from the *right* tree (when thinking of gf3 = gf/gf2). In hatchet, those nodes contained in only one of the two trees are initialized with a value of nan, and are colored in blue.

```
>>> caliper_file_1core = 'lulesh-annotation-profile-1core.json'
>>> caliper_file_64cores = 'lulesh-annotation-profile-64cores.json'
>>> gf = ht.GraphFrame.from_caliper_json(caliper_file_1core)
>>> gf2 = ht.GraphFrame.from_caliper_json(caliper_file_64cores)
>>> gf.drop_index_levels()
>>> gf2.drop_index_levels()
>>> gf3 = gf/gf2
>>> gf3.tree(invert_colormap=True)
```

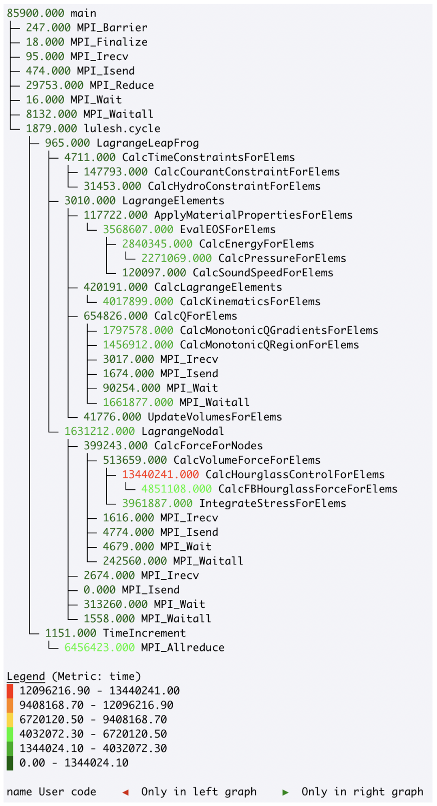


```
59923.000 main
├─ 75.000 MPI_Barrier
├─ 8.000 MPI_Finalize
├─ 41.000 MPI_Reduce
└─ 1460.000 lulesh.cycle
   ├─ 892.000 LagrangeLeapFrog
   │  ├─ 3811.000 CalcTimeConstraintsForElems
   │  │  ├─ 110792.000 CalcCourantConstraintForElems
   │  │  └─ 25759.000 CalcHydroConstraintForElems
   │  ├─ 1328.000 LagrangeElements
   │  │  ├─ 76882.000 ApplyMaterialPropertiesForElems
   │  │  │  └─ 1723555.000 EvalEOSForElems
   │  │  │     ├─ 1823877.000 CalcEnergyForElems
   │  │  │     │  └─ 1512447.000 CalcPressureForElems
   │  │  │     └─ 71141.000 CalcSoundSpeedForElems
   │  │  ├─ 197762.000 CalcLagrangeElements
   │  │  │  └─ 3160618.000 CalcKinematicsForElems
   │  │  ├─ 212834.000 CalcQForElems
   │  │  │  ├─ 1379143.000 CalcMonotonicQGradientsForElems
   │  │  │  └─ 896384.000 CalcMonotonicQRegionForElems
   │  │  └─ 26698.000 UpdateVolumesForElems
   │  └─ 333306.000 LagrangeNodal
   │     └─ 117149.000 CalcForceForNodes
   │        └─ 118224.000 CalcVolumeForceForElems
   │           ├─ 8523384.000 CalcHourglassControlForElems
   │           │  └─ 3832556.000 CalcFBHourglassForceForElems
   │           └─ 3127526.000 IntegrateStressForElems
   └─ 673.000 TimeIncrement
      └─ 1481.000 MPI_Allreduce

Legend (Metric: time)
🟥 7671046.40 - 8523384.00
🟧 5966371.20 - 7671046.40
🟨 4261696.00 - 5966371.20
🟩 2557020.80 - 4261696.00
🟩 852345.60 - 2557020.80
🟩 8.00 - 852345.60

name User code    ◀ Only in left graph    ▶ Only in right graph
```

/

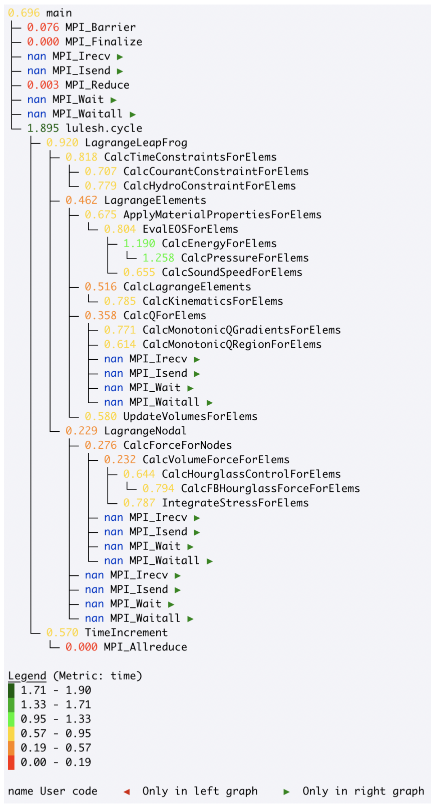


```
85900.000 main
├─ 247.000 MPI_Barrier
├─ 18.000 MPI_Finalize
├─ 95.000 MPI_Irecv
├─ 474.000 MPI_Isend
├─ 29753.000 MPI_Reduce
├─ 16.000 MPI_Wait
├─ 8132.000 MPI_Waitall
└─ 1879.000 lulesh.cycle
   ├─ 965.000 LagrangeLeapFrog
   │  ├─ 4711.000 CalcTimeConstraintsForElems
   │  │  ├─ 147793.000 CalcCourantConstraintForElems
   │  │  └─ 31453.000 CalcHydroConstraintForElems
   │  ├─ 3010.000 LagrangeElements
   │  │  ├─ 117722.000 ApplyMaterialPropertiesForElems
   │  │  │  └─ 3568607.000 EvalEOSForElems
   │  │  │     ├─ 2840345.000 CalcEnergyForElems
   │  │  │     │  └─ 2271069.000 CalcPressureForElems
   │  │  │     └─ 120097.000 CalcSoundSpeedForElems
   │  │  ├─ 420191.000 CalcLagrangeElements
   │  │  │  └─ 4017899.000 CalcKinematicsForElems
   │  │  ├─ 654826.000 CalcQForElems
   │  │  │  ├─ 1797578.000 CalcMonotonicQGradientsForElems
   │  │  │  ├─ 1456912.000 CalcMonotonicQRegionForElems
   │  │  │  ├─ 3017.000 MPI_Irecv
   │  │  │  ├─ 1674.000 MPI_Isend
   │  │  │  ├─ 90254.000 MPI_Wait
   │  │  │  └─ 1661877.000 MPI_Waitall
   │  │  └─ 41776.000 UpdateVolumesForElems
   │  └─ 1631212.000 LagrangeNodal
   │     ├─ 399243.000 CalcForceForNodes
   │     │  ├─ 513659.000 CalcVolumeForceForElems
   │     │  │  ├─ 13440241.000 CalcHourglassControlForElems
   │     │  │  │  └─ 4851108.000 CalcFBHourglassForceForElems
   │     │  │  └─ 3961887.000 IntegrateStressForElems
   │     │  ├─ 1616.000 MPI_Irecv
   │     │  ├─ 4774.000 MPI_Isend
   │     │  ├─ 4679.000 MPI_Wait
   │     │  └─ 242560.000 MPI_Waitall
   │     ├─ 2674.000 MPI_Irecv
   │     ├─ 0.000 MPI_Isend
   │     ├─ 313260.000 MPI_Wait
   │     └─ 1558.000 MPI_Waitall
   └─ 1151.000 TimeIncrement
      └─ 6456423.000 MPI_Allreduce

Legend (Metric: time)
🟥 12096216.90 - 13440241.00
🟧 9408168.70 - 12096216.90
🟨 6720120.50 - 9408168.70
🟩 4032072.30 - 6720120.50
🟩 1344024.10 - 4032072.30
🟩 0.00 - 1344024.10

name User code    ◀ Only in left graph    ▶ Only in right graph
```

=



```
0.696 main
├─ 0.076 MPI_Barrier
├─ 0.000 MPI_Finalize
├─ nan MPI_Irecv ▶
├─ nan MPI_Isend ▶
├─ 0.003 MPI_Reduce
├─ nan MPI_Wait ▶
├─ nan MPI_Waitall ▶
└─ 1.895 lulesh.cycle
   ├─ 0.920 LagrangeLeapFrog
   │  ├─ 0.818 CalcTimeConstraintsForElems
   │  │  ├─ 0.707 CalcCourantConstraintForElems
   │  │  └─ 0.779 CalcHydroConstraintForElems
   │  ├─ 0.462 LagrangeElements
   │  │  ├─ 0.675 ApplyMaterialPropertiesForElems
   │  │  │  └─ 0.804 EvalEOSForElems
   │  │  │     ├─ 1.190 CalcEnergyForElems
   │  │  │     │  └─ 1.258 CalcPressureForElems
   │  │  │     └─ 0.655 CalcSoundSpeedForElems
   │  │  ├─ 0.516 CalcLagrangeElements
   │  │  │  └─ 0.785 CalcKinematicsForElems
   │  │  ├─ 0.358 CalcQForElems
   │  │  │  ├─ 0.771 CalcMonotonicQGradientsForElems
   │  │  │  ├─ 0.614 CalcMonotonicQRegionForElems
   │  │  │  ├─ nan MPI_Irecv ▶
   │  │  │  ├─ nan MPI_Isend ▶
   │  │  │  ├─ nan MPI_Wait ▶
   │  │  │  └─ nan MPI_Waitall ▶
   │  │  └─ 0.580 UpdateVolumesForElems
   │  └─ 0.229 LagrangeNodal
   │     ├─ 0.276 CalcForceForNodes
   │     │  ├─ 0.232 CalcVolumeForceForElems
   │     │  │  ├─ 0.644 CalcHourglassControlForElems
   │     │  │  │  └─ 0.794 CalcFBHourglassForceForElems
   │     │  │  └─ 0.787 IntegrateStressForElems
   │     │  ├─ nan MPI_Irecv ▶
   │     │  ├─ nan MPI_Isend ▶
   │     │  ├─ nan MPI_Wait ▶
   │     │  └─ nan MPI_Waitall ▶
   │     ├─ nan MPI_Irecv ▶
   │     ├─ nan MPI_Isend ▶
   │     ├─ nan MPI_Wait ▶
   │     └─ nan MPI_Waitall ▶
   └─ 0.570 TimeIncrement
      └─ 0.000 MPI_Allreduce

Legend (Metric: time)
🟩 1.71 - 1.90
🟩 1.33 - 1.71
🟩 0.95 - 1.33
🟨 0.57 - 0.95
🟧 0.19 - 0.57
🟥 0.00 - 0.19

name User code    ◀ Only in left graph    ▶ Only in right graph
```

CHAPTER 5

Publications and Presentations

5.1 Publications

- Stephanie Brink, Ian Lumsden, Connor Scully-Allison, Katy Williams, Olga Pearce, Todd Gamblin, Michela Taufer, Katherine Isaacs, Abhinav Bhatele. Usability and Performance Improvements in Hatchet. Presented at the ProTools 2020 Workshop, held in conjunction with the International Conference for High Performance Computing, Networking, Storage and Analysis (SC '20), held virtually.
- Abhinav Bhatele, Stephanie Brink, and Todd Gamblin. Hatchet: Pruning the Overgrowth in Parallel Profiles. In Proceedings of the International Conference for High Performance Computing, Networking, Storage and Analysis (SC '19), Denver, CO.

5.2 Posters

- Ian Lumsden. Graph-Based Profiling Analysis using Hatchet. Presented at SC '20. Slides | Video Presentation
- Suraj P. Kesavan, Harsh Bhatia, Abhinav Bhatele, Stephanie Brink, Olga Pearce, Todd Gamblin, Peer-Timo Bremer, and Kwan-Liu Ma. *Scalable Comparative Visualization of Ensembles of Call Graphs Using CallFlow*. Presented at SC '20.

5.3 Tutorials

- Performance Analysis using Hatchet, LLNL, July 29/31, 2020.

CHAPTER 6

hatchet package

6.1 Subpackages

6.1.1 hatchet.cython_modules package

Subpackages

hatchet.cython_modules.libs package

Submodules

hatchet.cython_modules.libs.subtract_metrics module

Module contents

Submodules

hatchet.cython_modules.subtract_metrics module

Module contents

6.1.2 hatchet.external package

Submodules

hatchet.external.console module

class `hatchet.external.console.`**`ConsoleRenderer`**(*unicode=False*, *color=False*)

Bases: `object`

colors_disabled = <hatchet.external.console.ConsoleRenderer.colors_disabled object>

class colors_enabled
Bases: `object`

bg_white_255 = '\x1b[48;5;246m'

blue = '\x1b[34m'

colormap = ['\x1b[38;5;196m', '\x1b[38;5;208m', '\x1b[38;5;220m', '\x1b[38;5;46m',

cyan = '\x1b[36m'

dark_gray_255 = '\x1b[38;5;232m'

end = '\x1b[0m'

faint = '\x1b[2m'

left = '\x1b[38;5;160m'

right = '\x1b[38;5;28m'

render(*roots*, *dataframe*, ***kwargs*)

render_frame(*node*, *dataframe*, *indent=''*, *child_indent=''*)

render_legend()

render_preamble()

Module contents

6.1.3 hatchet.readers package

Submodules

hatchet.readers.caliper_reader module

class hatchet.readers.caliper_reader.**CaliperReader**(*filename_or_stream*, *query=''*)
Bases: `object`

Read in a Caliper file (*cali* or split JSON) or file-like object.

create_graph()

read()
Read the caliper JSON file to extract the calling context tree.

read_json_sections()

hatchet.readers.gprof_dot_reader module

class hatchet.readers.gprof_dot_reader.**GprofDotReader**(*filename*)
Bases: `object`

Read in gprof/callgrind output in dot format generated by gprof2dot.

create_graph()
Read the DOT files to create a graph.

read()
Read the DOT file generated by gprof2dot to create a graphframe. The DOT file contains a call graph.

hatchet.readers.hpctoolkit_reader module

class hatchet.readers.hpctoolkit_reader.**HPCToolkitReader**(*dir_name*)

Bases: `object`

Read in the various sections of an HPCToolkit experiment.xml file and metric-db files.

create_node_dict(*nid*, *hnode*, *name*, *node_type*, *src_file*, *line*, *module*)
Create a dict with all the node attributes.

fill_tables()
Read certain sections of the experiment.xml file to create dicts of load modules, src_files, procedure_names, and metric_names.

parse_xml_children(*xml_node*, *hnode*)
Parses all children of an XML node.

parse_xml_node(*xml_node*, *parent_nid*, *parent_line*, *hparent*)
Parses an XML node and its children recursively.

read()
Read the experiment.xml file to extract the calling context tree and create a dataframe out of it. Then merge the two dataframes to create the final dataframe.

Returns new GraphFrame with HPCToolkit data.

Return type (*GraphFrame*)

read_all_metricdb_files()
Read all the metric-db files and create a dataframe with num_nodes X num_metricdb_files rows and num_metrics columns. Three additional columns store the node id, MPI process rank, and thread id (if applicable).

hatchet.readers.hpctoolkit_reader.**init_shared_array**(*buf_*)
Initialize shared array.

hatchet.readers.hpctoolkit_reader.**read_metricdb_file**(*args*)
Read a single metricdb file into a 1D array.

Module contents

6.1.4 hatchet.util package

Submodules

hatchet.util.config module

hatchet.util.deprecated module

hatchet.util.deprecated.**deprecated_params**(***old_to_new*)

hatchet.util.deprecated.**rename_kwargs**(*fname*, *old_to_new*, *kwargs*)

hatchet.util.dot module

hatchet.util.dot.**to_dot**(*hnode*, *dataframe*, *metric*, *name*, *rank*, *thread*, *threshold*, *visited*)
Write to graphviz dot format.

`hatchet.util.dot.`**`trees_to_dot`**(*roots*, *dataframe*, *metric*, *name*, *rank*, *thread*, *threshold*)
Calls to_dot in turn for each tree in the graph/forest.

hatchet.util.executable module

`hatchet.util.executable.`**`which`**(*executable*)
Finds an *executable* in the user's PATH like command-line which.

Parameters **`executable`** (`str`) – executable to search for

hatchet.util.profiler module

`class` `hatchet.util.profiler.`**`Profiler`**
Bases: `object`

Wrapper class around cProfile. Exports a pstats file to be read by the pstats reader.

`reset`()
Description: Resets the profilier.

`start`()
Description: Place before the block of code to be profiled.

`stop`()
Description: Place at the end of the block of code being profiled.

`write_to_file`(*filename=", add_pstats_files=[]*)
Description: Write the pstats object to a binary file to be read in by an appropriate source.

`hatchet.util.profiler.`**`print_incomptable_msg`**(*stats_file*)
Function which makes the syntax cleaner in Profiler.write_to_file().

hatchet.util.timer module

`class` `hatchet.util.timer.`**`Timer`**
Bases: `object`

Simple phase timer with a context manager.

`end_phase`()

`phase`(*name*)

`start_phase`(*phase*)

Module contents

6.2 Submodules

6.3 hatchet.frame module

`class` `hatchet.frame.`**`Frame`**(*attrs=None*, ***kwargs*)
Bases: `object`

The frame index for a node. The node only stores its frame.

Parameters **attrs** (*dict*) – dictionary of attributes and values

copy()

get(*name*, *default=None*)

tuple_repr
Make a tuple of attributes and values based on reader.

values(*names*)
Return a tuple of attribute values from this Frame.

6.4 hatchet.graph module

class hatchet.graph.**Graph**(*roots*)
Bases: `object`

A possibly multi-rooted tree or graph from one input dataset.

copy(*old_to_new=None*)
Create and return a copy of this graph.

Parameters **old_to_new** (*dict, optional*) – if provided, this dictionary will be populated with mappings from old node -> new node

enumerate_depth()

enumerate_traverse()

find_merges()
Find nodes that have the same parent and frame.

Find nodes that have the same parent and duplicate frame, and return a mapping from nodes that should be eliminated to nodes they should be merged into.

Returns dictionary from nodes to their merge targets

Return type (dict)

static from_lists(**roots*)
Convenience method to invoke Node.from_lists() on each root value.

is_tree()
True if this graph is a tree, false otherwise.

merge_nodes(*merges*)
Merge some nodes in a graph into others.

`merges` is a dictionary keyed by old nodes, with values equal to the nodes that they need to be merged into. Old nodes' parents and children are connected to the new node.

Parameters **merges** (*dict*) – dictionary from source nodes -> targets

normalize()

traverse(*order='pre'*, *attrs=None*, *visited=None*)
Preorder traversal of all roots of this Graph.

Parameters **attrs** (*list or str, optional*) – If provided, extract these fields from nodes while traversing and yield them. See `traverse()` for details.

Only preorder traversal is currently supported.

union (*other*, *old_to_new=None*)

Create the union of self and other and return it as a new Graph.

This creates a new graph and does not modify self or other. The new Graph has entirely new nodes.

Parameters

- **other** (Graph) – another Graph
- **old_to_new** (*dict, optional*) – if provided, this dictionary will be populated with mappings from old node -> new node

Returns new Graph containing all nodes and edges from self and other

Return type (*Graph*)

hatchet.graph.**index_by** (*attr*, *objects*)

Put objects into lists based on the value of an attribute.

Returns dictionary of lists of objects, keyed by attribute value

Return type (dict)

6.5 hatchet.graphframe module

exception hatchet.graphframe.**EmptyFilter**

Bases: Exception

Raised when a filter would otherwise return an empty GraphFrame.

class hatchet.graphframe.**GraphFrame** (*graph*, *dataframe*, *exc_metrics=None*, *inc_metrics=None*)

Bases: object

An input dataset is read into an object of this type, which includes a graph and a dataframe.

add (*other*, **args*, ***kwargs*)

Returns the column-wise sum of two graphframes as a new graphframe.

This graphframe is the union of self's and other's graphs, and does not modify self or other.

Returns new graphframe

Return type (*GraphFrame*)

copy ()

Return a shallow copy of the graphframe.

This copies the DataFrame, but the Graph is shared between self and the new GraphFrame.

deepcopy ()

Return a copy of the graphframe.

div (*other*, **args*, ***kwargs*)

Returns the column-wise float division of two graphframes as a new graphframe.

This graphframe is the union of self's and other's graphs, and does not modify self or other.

Returns new graphframe

Return type (*GraphFrame*)

drop_index_levels (*function=<function mean>*)

Drop all index levels but *node*.

filter (*filter_obj*, *squash=True*)
Filter the dataframe using a user-supplied function.

Parameters

- **filter_obj** (`callable, list, or QueryMatcher`) – the filter to apply to the GraphFrame.
- **squash** (`boolean, optional`) – if True, automatically call squash for the user.

static from_caliper (*filename*, *query*)
Read in a Caliper *cali* file.

Parameters

- **filename** (`str`) – name of a Caliper output file in *.cali* format
- **query** (`str`) – cali-query in CalQL format

static from_caliper_json (*filename_or_stream*)
Read in a Caliper *cali-query* JSON-split file or an open file object.

Parameters **filename_or_stream** (`str or file-like`) – name of a Caliper JSON-split output file, or an open file object to read one

static from_cprofile (*filename*)
Read in a pstats/prof file generated using python's cProfile.

static from_gprof_dot (*filename*)
Read in a DOT file generated by gprof2dot.

static from_hpctoolkit (*dirname*)
Read an HPCToolkit database directory into a new GraphFrame.

Parameters **dirname** (`str`) – parent directory of an HPCToolkit experiment.xml file

Returns new GraphFrame containing HPCToolkit profile data

Return type (*GraphFrame*)

static from_lists (**lists*)
Make a simple GraphFrame from lists.

This creates a Graph from lists (see `Graph.from_lists()`) and uses it as the index for a new GraphFrame. Every node in the new graph has exclusive time of 1 and inclusive time is computed automatically.

static from_literal (*graph_dict*)
Create a GraphFrame from a list of dictionaries.

static from_pyinstrument (*filename*)
Read in a JSON file generated using Pyinstrument.

groupby_aggregate (*groupby_function*, *agg_function*)
Groupby-aggregate dataframe and reindex the Graph.

Reindex the graph to match the groupby-aggregated dataframe.

Update the frame attributes to contain those columns in the dataframe index.

Parameters

- **self** (`graphframe`) – self's graphframe
- **groupby_function** – groupby function on dataframe
- **agg_function** – aggregate function on dataframe

Returns new graphframe with reindexed graph and groupby-aggregated dataframe

Return type (*GraphFrame*)

mul(*other*, **args*, ***kwargs*)
Returns the column-wise float multiplication of two graphframes as a new graphframe.

This graphframe is the union of self's and other's graphs, and does not modify self or other.

Returns new graphframe

Return type (*GraphFrame*)

squash()
Rewrite the Graph to include only nodes present in the DataFrame's rows.

This can be used to simplify the Graph, or to normalize Graph indexes between two GraphFrames.

sub(*other*, **args*, ***kwargs*)
Returns the column-wise difference of two graphframes as a new graphframe.

This graphframe is the union of self's and other's graphs, and does not modify self or other.

Returns new graphframe

Return type (*GraphFrame*)

subgraph_sum(*columns*, *out_columns=None*, *function=<function GraphFrame.<lambda>>*)
Compute sum of elements in subgraphs.

For each row in the graph, `out_columns` will contain the element-wise sum of all values in `columns` for that row's node and all of its descendants.

This algorithm is worst-case quadratic in the size of the graph, so we try to call `subtree_sum` if we can. In general, there is not a particularly efficient algorithm known for subgraph sums, so this does about as well as we know how.

Parameters

- **columns** (*list of str*) – names of columns to sum (default: all columns)
- **out_columns** (*list of str*) – names of columns to store results (default: in place)
- **function** (*callable*) – associative operator used to sum elements, sum of an all-NA series is NaN (default: sum(min_count=1))

subtree_sum(*columns*, *out_columns=None*, *function=<function GraphFrame.<lambda>>*)
Compute sum of elements in subtrees. Valid only for trees.

For each row in the graph, `out_columns` will contain the element-wise sum of all values in `columns` for that row's node and all of its descendants.

This algorithm will multiply count nodes with in-degree higher than one – i.e., it is only correct for trees. Prefer using `subgraph_sum` (which calls `subtree_sum` if it can), unless you have a good reason not to.

Parameters

- **columns** (*list of str*) – names of columns to sum (default: all columns)
- **out_columns** (*list of str*) – names of columns to store results (default: in place)
- **function** (*callable*) – associative operator used to sum elements, sum of an all-NA series is NaN (default: sum(min_count=1))

to_dot(*metric='time'*, *name='name'*, *rank=0*, *thread=0*, *threshold=0.0*)
Write the graph in the graphviz dot format: https://www.graphviz.org/doc/info/lang.html

to_flamegraph(*metric='time'*, *name='name'*, *rank=0*, *thread=0*, *threshold=0.0*)
Write the graph in the folded stack output required by FlameGraph http://www.brendangregg.com/flamegraphs.html

to_literal(*name='name'*, *rank=0*, *thread=0*)
Format this graph as a list of dictionaries for Roundtrip visualizations.

tree(*metric_column='time'*, *precision=3*, *name_column='name'*, *expand_name=False*, *context_column='file'*, *rank=0*, *thread=0*, *depth=10000*, *highlight_name=False*, *invert_colormap=False*)
Format this graphframe as a tree and return the resulting string.

unify(*other*)
Returns a unified graphframe.

Ensure self and other have the same graph and same node IDs. This may change the node IDs in the dataframe.

Update the graphs in the graphframe if they differ.

update_inclusive_columns()
Update inclusive columns (typically after operations that rewire the graph.

exception `hatchet.graphframe.`**InvalidFilter**
Bases: `Exception`

Raised when an invalid argument is passed to the filter function.

6.6 hatchet.node module

exception `hatchet.node.`**MultiplePathError**
Bases: `Exception`

Raised when a node is asked for a single path but has multiple.

class `hatchet.node.`**Node**(*frame_obj*, *parent=None*, *hnid=-1*, *depth=-1*)
Bases: `object`

A node in the graph. The node only stores its frame.

add_child(*node*)
Adds a child to this node's list of children.

add_parent(*node*)
Adds a parent to this node's list of parents.

copy()
Copy this node without preserving parents or children.

dag_equal(*other*, *vs=None*, *vo=None*)
Check if DAG rooted at self has the same structure as that rooted at other.

classmethod from_lists(*lists*)
Construct a hierarchy of nodes from recursive lists.

For example, this will construct a simple tree:

```
Node.from_lists(
    ["a",
        ["b", "d", "e"],
        ["c", "f", "g"],
```

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(continued from previous page)

```
    ]
)
```

```
     a
    / \
   b   c
 / |   | \
d  e   f  g
```

And this will construct a simple diamond DAG:

```
d = Node(Frame(name="d"))
Node.from_lists(
    ["a",
        ["b", d],
        ["c", d]
    ]
)
```

```
  a
 / \
b   c
 \ /
  d
```

In the above examples, the 'a' represents a Node with its *frame == Frame(name="a")*.

path (*attrs=None*)
Path to this node from root. Raises if there are multiple paths.

Parameters **attrs** (*str or list, optional*) – attribute(s) to extract from Frames

This is useful for trees (where each node only has one path), as it just gets the only element from `self.paths`. This will fail with a MultiplePathError if there is more than one path to this node.

paths (*attrs=None*)
List of tuples, one for each path from this node to any root.

Parameters **attrs** (*str or list, optional*) – attribute(s) to extract from Frames

Paths are tuples of Frame objects, or, if attrs is provided, they are paths containing the requested attributes.

traverse (*order='pre', attrs=None, visited=None*)
Traverse the tree depth-first and yield each node.

Parameters

- **order** (*str*) – "pre" or "post" for preorder or postorder (default: pre)
- **attrs** (*list or str, optional*) – if provided, extract these fields from nodes while traversing and yield them
- **visited** (*dict, optional*) – dictionary in which each visited node's in-degree will be stored

hatchet.node.**traversal_order** (*node*)
Deterministic key function for sorting nodes in traversals.

6.7 hatchet.query_matcher module

exception `hatchet.query_matcher.`**`InvalidQueryFilter`**

Bases: `Exception`

Raised when a query filter does not have a valid syntax

exception `hatchet.query_matcher.`**`InvalidQueryPath`**

Bases: `Exception`

Raised when a query does not have the correct syntax

class `hatchet.query_matcher.`**`QueryMatcher`**(*query=None*)

Bases: `object`

Process and apply queries to GraphFrames.

`apply`(*gf*)

Apply the query to a GraphFrame.

Parameters **gf** (`GraphFrame`) – the GraphFrame on which to apply the query.

Returns A list of lists representing the set of paths that match this query.

Return type (list)

`match`(*wildcard_spec='.', filter_func=<function QueryMatcher.<lambda>>*)

Start a query with a root node described by the arguments.

Parameters

- **wildcard_spec** (*str, optional, ".", "*", or "+"*) – the wildcard status of the node (follows standard Regex syntax)
- **filter_func** (*callable, optional*) – a callable accepting only a row from a Pandas DataFrame that is used to filter this node in the query

Returns The instance of the class that called this function (enables fluent design).

Return type (*QueryMatcher*)

`rel`(*wildcard_spec='.', filter_func=<function QueryMatcher.<lambda>>*)

Add another edge and node to the query.

Parameters

- **wildcard_spec** (*str, optional, ".", "*", or "+"*) – the wildcard status of the node (follows standard Regex syntax)
- **filter_func** (*callable, optional*) – a callable accepting only a row from a Pandas DataFrame that is used to filter this node in the query

Returns The instance of the class that called this function (enables fluent design).

Return type (*QueryMatcher*)

6.8 Module contents

CHAPTER 7

Indices and tables

- genindex
- modindex
- search

Python Module Index

Index