onnx_profile_ort

June 30, 2022

1 Profiling with onnxruntime

The notebook profiles the execution of an ONNX graph built from a *KMeans* model and executed with *onnxruntime*. It then study the decomposition of one einsum equation into more simple operators.

[1]:
```
from jyquickhelper import add_notebook_menu
add_notebook_menu()
```

[1]:
```
<IPython.core.display.HTML object>
```

[2]:
```
%matplotlib inline
```

[3]:
```
%load_ext mlprodict
```

1.1 KMeans

1.1.1 Builds a KMeans

[4]:
```
from sklearn.datasets import make_classification
X, y = make_classification(100000)
```

[5]:
```
from sklearn.cluster import KMeans
km = KMeans(max_iter=10)
km.fit(X)
```

[5]:
```
KMeans(max_iter=10)
```

[6]:
```
import numpy
from mlprodict.onnx_conv import to_onnx
onx = to_onnx(km, X[:1].astype(numpy.float32))
```

[7]:
```
%onnxview onx
```

[7]:
```
<jyquickhelper.jspy.render_nb_js_dot.RenderJsDot at 0x26206ad88b0>
```

1.1.2 Json

Another way to look into a model.

[8]:
```
from mlprodict.onnxrt import OnnxInference
```

```
oinf = OnnxInference(onx)
js = oinf.to_json()
```

[9]:
```
import json
from io import StringIO
from jyquickhelper import JSONJS
JSONJS(json.load(StringIO(oinf.to_json())))
```

[9]: <jyquickhelper.jspy.render_nb_json.RenderJSON at 0x262341a3370>

1.1.3 Profiling

[10]:
```
from mlprodict.onnxrt import OnnxInference

oinf = OnnxInference(onx, runtime="onnxruntime1",
                     runtime_options={"enable_profiling": True})
```

[11]:
```
for i in range(0, 111):
    oinf.run({"X": X.astype(numpy.float32)})
```

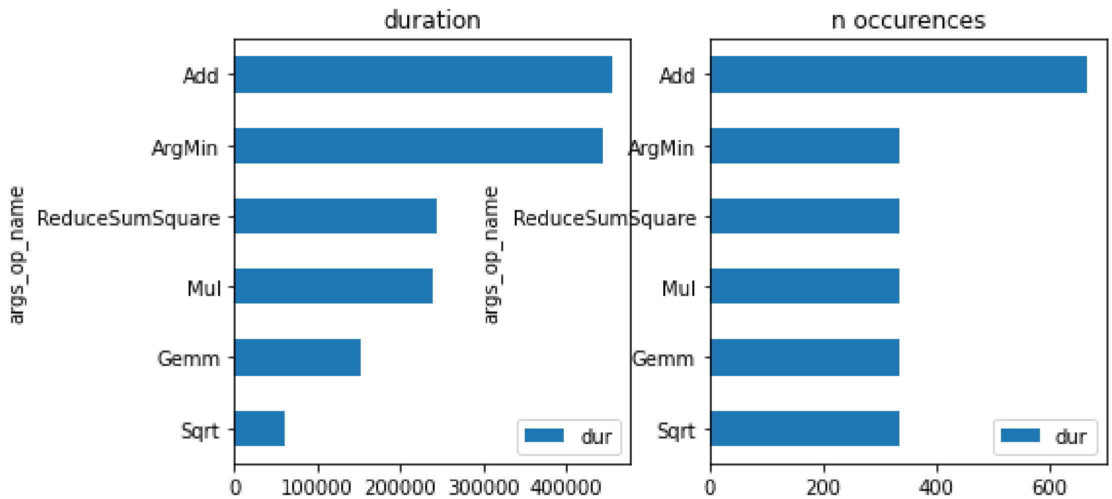
[12]:
```
df = oinf.get_profiling(as_df=True)
df
```

[12]:
```
          cat     pid     tid    dur       ts ph  \
0     Session  106368  299276    596       12  X
1     Session  106368  299276   6925      670  X
2        Node  106368  299276      1    34854  X
3        Node  106368  299276   2939    34869  X
4        Node  106368  299276      0    37872  X
…         …       …       …      …        … ..
2550     Node  106368  299276      0  2394227  X
2551     Node  106368  299276   3511  2394228  X
2552     Node  106368  299276      0  2397761  X
2553  Session  106368  299276  11774  2385990  X
2554  Session  106368  299276  11789  2385982  X

                                name     args_op_name         args_provider  \
0                 model_loading_array              NaN                   NaN
1              session_initialization              NaN                   NaN
2     Re_ReduceSumSquare_fence_before  ReduceSumSquare                   NaN
3      Re_ReduceSumSquare_kernel_time  ReduceSumSquare  CPUExecutionProvider
4      Re_ReduceSumSquare_fence_after  ReduceSumSquare                   NaN
…                                  …                …                     …
2550           Ar_ArgMin_fence_before           ArgMin                   NaN
2551            Ar_ArgMin_kernel_time           ArgMin  CPUExecutionProvider
2552            Ar_ArgMin_fence_after           ArgMin                   NaN
2553      SequentialExecutor::Execute              NaN                   NaN
2554                        model_run              NaN                   NaN

     args_graph_index args_parameter_size  \
0                 NaN                 NaN
1                 NaN                 NaN
2                 NaN                 NaN
```

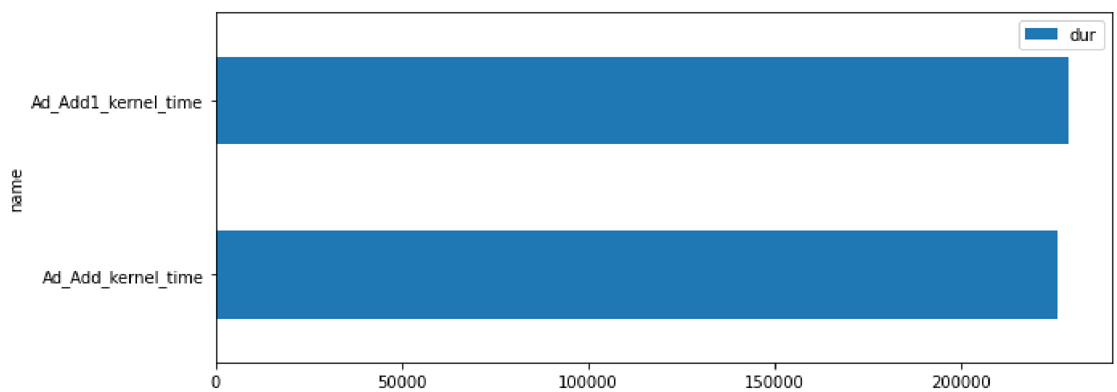
```
3                  0                  0
4                NaN                NaN
…                …                  …
2550             NaN                NaN
2551               5                  0
2552             NaN                NaN
2553             NaN                NaN
2554             NaN                NaN

                           args_thread_scheduling_stats args_exec_plan_index  \
0                                                   NaN                  NaN
1                                                   NaN                  NaN
2                                                   NaN                  NaN
3     {'main_thread': {'thread_pool_name': 'session-…                    0
4                                                   NaN                  NaN
…                                                 …                    …
2550                                                NaN                  NaN
2551  {'main_thread': {'thread_pool_name': 'session-…                    5
2552                                                NaN                  NaN
2553                                                NaN                  NaN
2554                                                NaN                  NaN

     args_activation_size args_output_size
0                     NaN              NaN
1                     NaN              NaN
2                     NaN              NaN
3                 8000000           400000
4                     NaN              NaN
…                   …                …
2550                  NaN              NaN
2551              3200000           800000
2552                  NaN              NaN
2553                  NaN              NaN
2554                  NaN              NaN

[2555 rows x 15 columns]
```

[13]:

```python
import matplotlib.pyplot as plt
gr_dur = df[['dur', "args_op_name"]].groupby("args_op_name").sum().sort_values('dur')
gr_n = df[['dur', "args_op_name"]].groupby("args_op_name").count().sort_values('dur')
gr_n = gr_n.loc[gr_dur.index, :]

fig, ax = plt.subplots(1, 2, figsize=(8, 4))
gr_dur.plot.barh(ax=ax[0])
gr_n.plot.barh(ax=ax[1])
ax[0].set_title("duration")
ax[1].set_title("n occurences");
```




```
[14]: gr2 = df.loc[(df.args_op_name == 'Add') & (df.dur > 10), ['dur', "name"]].
      ↪groupby("name").sum().sort_values('dur')
      gr2.plot.barh(figsize=(10, 4));
```



1.1.4 onnxruntime

```
[15]: from onnxruntime import InferenceSession, RunOptions, SessionOptions
      so = SessionOptions()
      so.enable_profiling = True
      sess = InferenceSession(onx.SerializeToString(), so)
```

```
[16]: for i in range(0, 111):
          sess.run(None, {'X': X.astype(numpy.float32)}, )
```

```
[17]: prof = sess.end_profiling()
      prof
```

```
[17]: 'onnxruntime_profile__2021-05-13_13-58-59.json'
```

[18]:
```
with open(prof, "r") as f:
    js = json.load(f)

js[:3]
```

[18]:
```
[{'cat': 'Session',
  'pid': 106368,
  'tid': 299276,
  'dur': 450,
  'ts': 6,
  'ph': 'X',
  'name': 'model_loading_array',
  'args': {}},
 {'cat': 'Session',
  'pid': 106368,
  'tid': 299276,
  'dur': 3068,
  'ts': 498,
  'ph': 'X',
  'name': 'session_initialization',
  'args': {}},
 {'cat': 'Node',
  'pid': 106368,
  'tid': 299276,
  'dur': 1,
  'ts': 39069,
  'ph': 'X',
  'name': 'Re_ReduceSumSquare_fence_before',
  'args': {'op_name': 'ReduceSumSquare'}}]
```

[19]:
```
from pandas import DataFrame
from mlprodict.onnxrt.ops_whole.session import OnnxWholeSession

df = DataFrame(OnnxWholeSession.process_profiling(js))
df
```

[19]:
```
          cat     pid     tid    dur       ts ph  \
0     Session  106368  299276    450        6  X
1     Session  106368  299276   3068      498  X
2        Node  106368  299276      1    39069  X
3        Node  106368  299276   2804    39081  X
4        Node  106368  299276      0    41947  X
…         …       …       …      …        … ..
2550     Node  106368  299276      0  2530548  X
2551     Node  106368  299276   3501  2530550  X
2552     Node  106368  299276      0  2534074  X
2553  Session  106368  299276  14679  2519397  X
2554  Session  106368  299276  14701  2519386  X

                                 name     args_op_name         args_provider  \
0                 model_loading_array              NaN                   NaN
1              session_initialization              NaN                   NaN
2     Re_ReduceSumSquare_fence_before  ReduceSumSquare                   NaN
```

```
3      Re_ReduceSumSquare_kernel_time  ReduceSumSquare  CPUExecutionProvider
4      Re_ReduceSumSquare_fence_after  ReduceSumSquare                   NaN
…                                   …                …                     …
2550           Ar_ArgMin_fence_before           ArgMin                   NaN
2551            Ar_ArgMin_kernel_time           ArgMin  CPUExecutionProvider
2552            Ar_ArgMin_fence_after           ArgMin                   NaN
2553     SequentialExecutor::Execute              NaN                   NaN
2554                        model_run              NaN                   NaN

     args_graph_index args_parameter_size  \
0                 NaN                 NaN
1                 NaN                 NaN
2                 NaN                 NaN
3                   0                   0
4                 NaN                 NaN
…                   …                   …
2550              NaN                 NaN
2551                5                   0
2552              NaN                 NaN
2553              NaN                 NaN
2554              NaN                 NaN

                           args_thread_scheduling_stats args_exec_plan_index  \
0                                                   NaN                  NaN
1                                                   NaN                  NaN
2                                                   NaN                  NaN
3     {'main_thread': {'thread_pool_name': 'session-…                    0
4                                                   NaN                  NaN
…                                                     …                    …
2550                                                NaN                  NaN
2551  {'main_thread': {'thread_pool_name': 'session-…                    5
2552                                                NaN                  NaN
2553                                                NaN                  NaN
2554                                                NaN                  NaN

     args_activation_size args_output_size
0                     NaN              NaN
1                     NaN              NaN
2                     NaN              NaN
3                 8000000           400000
4                     NaN              NaN
…                       …                …
2550                  NaN              NaN
2551              3200000           800000
2552                  NaN              NaN
2553                  NaN              NaN
2554                  NaN              NaN

[2555 rows x 15 columns]
```

1.2 Einsum: `bsnh,btnh->bnts`

This section looks into the ONNX graph produces by the decomposition of an einsum equation into more simple ONNX operator (no einsum).

1.2.1 Three implementations

[20]:
```python
from mlprodict.testing.einsum import einsum as onx_einsum
from mlprodict.testing.einsum.einsum_fct import _einsum, enumerate_cached_einsum
from numpy import einsum as np_einsum
```

First classic numpy.

[21]:
```python
equation = "bsnh,btnh->bnts"

N = 2
inputs = [numpy.random.randn(N, N, N, N).astype(numpy.float32),
          numpy.random.randn(N, N, N, N).astype(numpy.float32)]
np_einsum(equation, *inputs)
```

[21]:
```
array([[[[-2.373884  , -0.63942796],
         [ 1.0523143 ,  5.659873  ]],

        [[ 2.589915  , -0.18050319],
         [-0.6200199 ,  3.793615  ]]],


       [[[-0.37409338,  0.19822143],
         [ 1.2049038 ,  3.1882448 ]],

        [[-0.05218329,  0.87404007],
         [ 0.12789296,  1.4745121 ]]]], dtype=float32)
```

Then einsum executed by *onnxruntime*:

[22]:
```python
onx_einsum(equation, *inputs, runtime='onnxruntime1', optimize=True, verbose=1,␣
↪decompose=False)
```

```
0.0026 best='sbhn,sthn->shtb': 100%|¿ ¿ ¿ ¿ ¿ ¿ ¿ ¿ ¿ ¿ | 121/121 [00:01<00:00, 85.29it/
↪s]
```

[22]:
```
array([[[[-2.373884  , -0.63942796],
         [ 1.0523144 ,  5.659873  ]],

        [[ 2.589915  , -0.18050319],
         [-0.62002003,  3.793615  ]]],


       [[[-0.37409338,  0.19822143],
         [ 1.2049038 ,  3.1882448 ]],

        [[-0.05218329,  0.87404007],
         [ 0.12789296,  1.474512  ]]]], dtype=float32)
```

[23]:
```
obj = _einsum(equation, runtime='onnxruntime1', optimize=True, verbose=1,
              decompose=False, dtype=inputs[0].dtype)
```

[24]:
```
%onnxview obj.onnx_
```

[24]:
```
<jyquickhelper.jspy.render_nb_js_dot.RenderJsDot at 0x26237ce29a0>
```

Same equation but decomposed.

[25]:
```
obj = _einsum(equation, runtime='onnxruntime1', optimize=True, verbose=1,
              decompose=True, dtype=inputs[0].dtype)
```

```
0.0025 best='hsnt,hbnt->hnbs': 100%|¿ ¿ ¿ ¿ ¿ ¿ ¿ ¿ ¿ ¿ | 121/121 [00:03<00:00, 34.54it/
↪s]
```

[26]:
```
%onnxview obj.onnx_
```

[26]:
```
<jyquickhelper.jspy.render_nb_js_dot.RenderJsDot at 0x2623b802df0>
```

[27]:
```
onx_einsum(equation, *inputs, runtime='onnxruntime1', optimize=True, verbose=1)
```

[27]:
```
array([[[[-2.373884  , -0.63942796],
         [ 1.0523144 ,  5.659873  ]],

        [[ 2.589915  , -0.18050319],
         [-0.62002003,  3.793615  ]]],


       [[[-0.37409338,  0.19822143],
         [ 1.2049038 ,  3.1882448 ]],

        [[-0.05218329,  0.87404007],
         [ 0.12789296,  1.474512  ]]]], dtype=float32)
```

1.2.2 First benchmark

[28]:
```
N = 20
inputs = [numpy.random.randn(N, N, N, N).astype(numpy.float32),
          numpy.random.randn(N, N, N, N).astype(numpy.float32)]
```

numpy.einsum

[29]:
```
%timeit numpy.einsum(equation, *inputs)
```

```
4.14 ms ± 350 µs per loop (mean ± std. dev. of 7 runs, 100 loops each)
```

onnxruntime einsum

[30]:
```
%timeit onx_einsum(equation, *inputs, runtime='onnxruntime1', optimize=True,␣
↪verbose=1, decompose=False)
```

```
736 µs ± 11.2 µs per loop (mean ± std. dev. of 7 runs, 1000 loops each)
```

onnxruntime decomposed einsum

[31]:
```
%timeit onx_einsum(equation, *inputs, runtime='onnxruntime1', optimize=True, verbose=1)
```

```
525 µs ± 12.4 µs per loop (mean ± std. dev. of 7 runs, 1000 loops each)
```

Let's disable the optimization to see the difference. The optimization goes through all the permutation of the letters of the equation and compares the computation time to find the best one.

[32]:
```
%timeit onx_einsum(equation, *inputs, runtime='onnxruntime1', optimize=False,␣
↪verbose=1, decompose=False)
```

```
761 µs ± 46.2 µs per loop (mean ± std. dev. of 7 runs, 1000 loops each)
```

It has no significant impact here but it has for the decomposition. The not optimized version is much slower.

[33]:
```
%timeit onx_einsum(equation, *inputs, runtime='onnxruntime1', optimize=False,␣
↪verbose=1)
```

```
1.41 ms ± 43.1 µs per loop (mean ± std. dev. of 7 runs, 1000 loops each)
```

1.2.3 Profiling of the not optimized version

Let's profile the graph obtained with the decomposition.

[34]:
```
obj = _einsum(equation, runtime='onnxruntime1', optimize=False, verbose=1,
              decompose=True, dtype=inputs[0].dtype)
onx = obj.onnx_
```

[35]:
```
obj.equation, obj.equation_
```

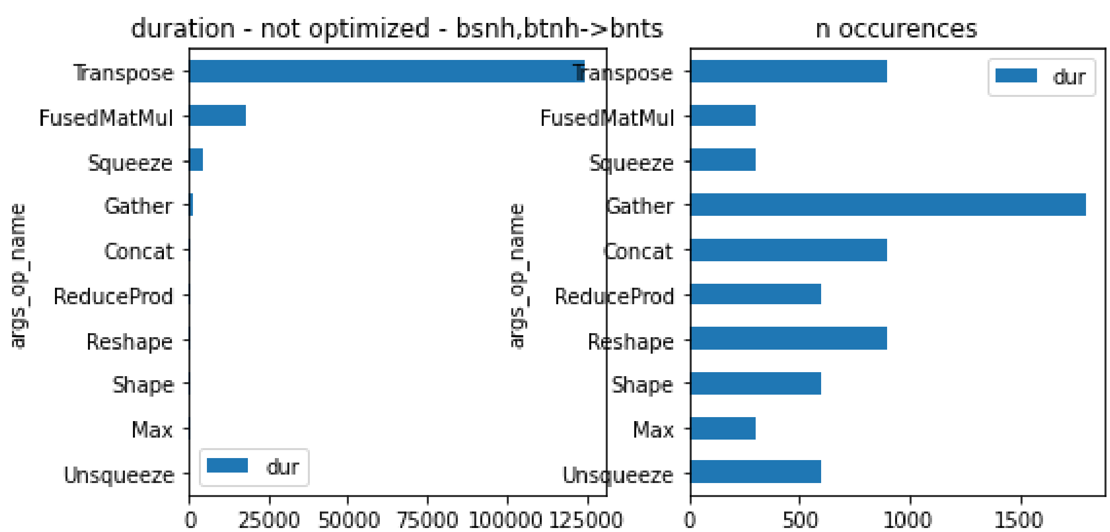
[35]:
```
('bsnh,btnh->bnts', 'bsnh,btnh->bnts')
```

[36]:
```
from mlprodict.onnxrt import OnnxInference

oinf = OnnxInference(onx, runtime="onnxruntime1",
                     runtime_options={"enable_profiling": True})

d_inputs = {'X0': inputs[0], 'X1': inputs[1]}
for i in range(0, 100):
    oinf.run(d_inputs)

df = oinf.get_profiling(as_df=True)
df.head()
```

[36]:
```
       cat     pid     tid   dur    ts ph  \
0  Session  106368  299276   705     4  X
1  Session  106368  299276  7019   987  X
2     Node  106368  299276     1  8320  X
3     Node  106368  299276     4  8327  X
4     Node  106368  299276     0  8372  X

                                 name args_op_name         args_provider  \
0                  model_loading_array          NaN                   NaN
1               session_initialization          NaN                   NaN
2  Unsqueeze3_2620928306480_fence_before    Unsqueeze                   NaN
```

```
3   Unsqueeze3_2620928306480_kernel_time    Unsqueeze  CPUExecutionProvider
4   Unsqueeze3_2620928306480_fence_after    Unsqueeze                   NaN

  args_graph_index args_parameter_size  \
0              NaN                 NaN
1              NaN                 NaN
2              NaN                 NaN
3                4                   8
4              NaN                 NaN

                        args_thread_scheduling_stats args_exec_plan_index  \
0                                                NaN                  NaN
1                                                NaN                  NaN
2                                                NaN                  NaN
3  {'main_thread': {'thread_pool_name': 'session-…                    4
4                                                NaN                  NaN

  args_activation_size args_output_size
0                  NaN              NaN
1                  NaN              NaN
2                  NaN              NaN
3               640000           640000
4                  NaN              NaN
```

[37]:
```
import matplotlib.pyplot as plt
gr_dur = df[['dur', "args_op_name"]].groupby("args_op_name").sum().sort_values('dur')
gr_n = df[['dur', "args_op_name"]].groupby("args_op_name").count().sort_values('dur')
gr_n = gr_n.loc[gr_dur.index, :]

fig, ax = plt.subplots(1, 2, figsize=(8, 4))
gr_dur.plot.barh(ax=ax[0])
gr_n.plot.barh(ax=ax[1])
ax[0].set_title("duration - not optimized - %s" % obj.equation_)
ax[1].set_title("n occurences");
```



1.2.4 Profiling of the optimized version

[38]:
```
obj = _einsum(equation, runtime='onnxruntime1', optimize=True, verbose=1,
              decompose=True, dtype=inputs[0].dtype)
onx = obj.onnx_
```

[39]:
```
obj.equation, obj.equation_
```

[39]:
```
('bsnh,btnh->bnts', 'hsnt,hbnt->hnbs')
```

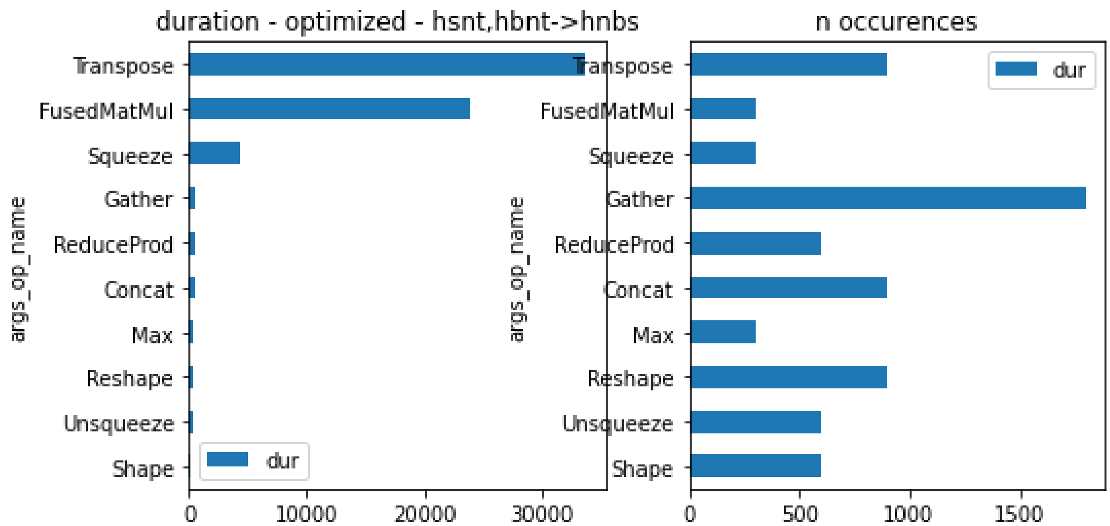
The second equation is the optimized equation.

[40]:
```
from mlprodict.onnxrt import OnnxInference

oinf = OnnxInference(onx, runtime="onnxruntime1",
                     runtime_options={"enable_profiling": True})

d_inputs = {'X0': inputs[0], 'X1': inputs[1]}
for i in range(0, 100):
    oinf.run(d_inputs)

df = oinf.get_profiling(as_df=True)
df.head()
```

[40]:
```
       cat     pid     tid  dur    ts ph  \
0  Session  106368  299276  1300     6  X
1  Session  106368  299276  7330  1720  X
2     Node  106368  299276     1  9376  X
3     Node  106368  299276     4  9383  X
4     Node  106368  299276     0  9422  X

                                  name args_op_name         args_provider  \
0                   model_loading_array          NaN                   NaN
1                session_initialization          NaN                   NaN
2  Unsqueeze3_2620928202160_fence_before    Unsqueeze                   NaN
3   Unsqueeze3_2620928202160_kernel_time    Unsqueeze  CPUExecutionProvider
4   Unsqueeze3_2620928202160_fence_after    Unsqueeze                   NaN

  args_graph_index args_parameter_size  \
0              NaN                 NaN
1              NaN                 NaN
2              NaN                 NaN
3                4                   8
4              NaN                 NaN

                       args_thread_scheduling_stats args_exec_plan_index  \
0                                               NaN                  NaN
1                                               NaN                  NaN
2                                               NaN                  NaN
3  {'main_thread': {'thread_pool_name': 'session-…                    4
4                                               NaN                  NaN

  args_activation_size args_output_size
```

```
0                  NaN              NaN
1                  NaN              NaN
2                  NaN              NaN
3               640000           640000
4                  NaN              NaN
```

[41]:
```
gr_dur = df[['dur', "args_op_name"]].groupby("args_op_name").sum().sort_values('dur')
gr_n = df[['dur', "args_op_name"]].groupby("args_op_name").count().sort_values('dur')
gr_n = gr_n.loc[gr_dur.index, :]

fig, ax = plt.subplots(1, 2, figsize=(8, 4))
gr_dur.plot.barh(ax=ax[0])
gr_n.plot.barh(ax=ax[1])
ax[0].set_title("duration - optimized - %s" % obj.equation_)
ax[1].set_title("n occurences");
```



onnxruntime was able to fuse MatMul with a transposition. That explains why it is faster.

[42]:
```
gr_dur = df[['dur', "args_op_name", "name"]].groupby(["args_op_name", "name"],␣
↪as_index=False).sum().sort_values('dur')
gr_dur
```

[42]:
```
   args_op_name                                          name    dur
0        Concat                           Concat12_fence_after      0
24       Gather                            Gather1_fence_after      0
25       Gather                           Gather1_fence_before      0
27       Gather                             Gather_fence_after      0
60    Transpose  Transpose02134_2620928192768_fence_after      0
..          …                                              …     …
56      Squeeze        Squeeze4_2620928194352_kernel_time   4339
59    Transpose  Transpose01324_2620928151024_kernel_time   8661
62    Transpose  Transpose02134_2620928192768_kernel_time  11487
65    Transpose  Transpose13024_2620928192816_kernel_time  13598
11  FusedMatMul             MatMul_With_Transpose_kernel_time  23847
```

```
[72 rows x 3 columns]
```

[43]:
```
gr_dur[gr_dur.args_op_name == "Transpose"]
```

[43]:
```
   args_op_name                                        name    dur
60    Transpose   Transpose02134_2620928192768_fence_after      0
57    Transpose   Transpose01324_2620928151024_fence_after      0
61    Transpose  Transpose02134_2620928192768_fence_before      0
58    Transpose  Transpose01324_2620928151024_fence_before      1
64    Transpose  Transpose13024_2620928192816_fence_before      1
63    Transpose   Transpose13024_2620928192816_fence_after      3
59    Transpose   Transpose01324_2620928151024_kernel_time   8661
62    Transpose   Transpose02134_2620928192768_kernel_time  11487
65    Transpose   Transpose13024_2620928192816_kernel_time  13598
```

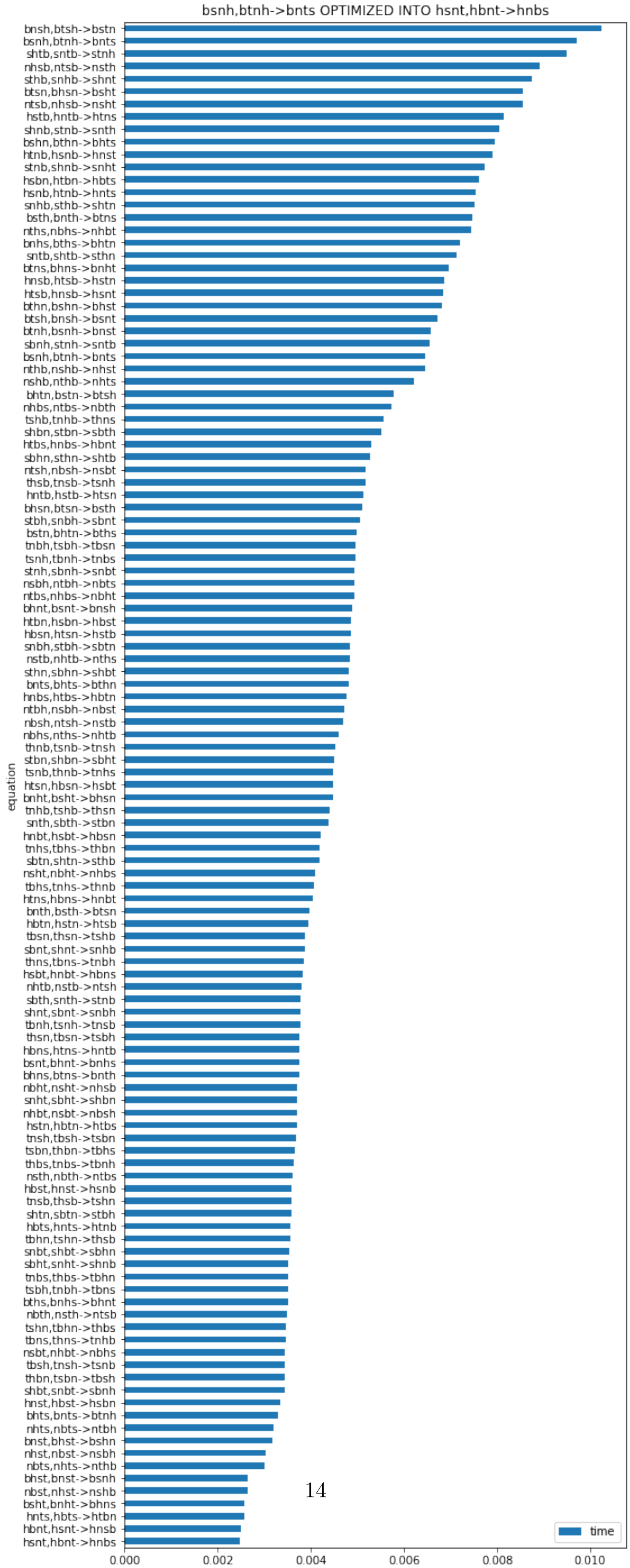
Let's draw again the graph to see which transpose is is which.

[44]:
```
%onnxview onx
```

[44]:
```
<jyquickhelper.jspy.render_nb_js_dot.RenderJsDot at 0x262366c7280>
```

The optimized looked into all permutations. We see that the letter ordering should be carefully chosen.

[45]:
```
import pandas
df = pandas.DataFrame(obj.timed_permutations_, columns=["time", "equation"])
df = df.sort_values('time')
df = df.set_index("equation")
ax = df.plot.barh(figsize=(8, 25))
ax.set_title("%s OPTIMIZED INTO %s" % (obj.equation, obj.equation_));
```



bsnh,btnh->bnts OPTIMIZED INTO hsnt,hbnt->hnbs
equation
time

```
[46]:
```