Scaling High-Performance Python with Minimal Effort

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Motivation

Data analytics is the greatest value driver in technology

Financial services need insights from data

- Exploit market data for financial modeling, etc.

High performance big data analytics is crucial

- Democratize HPC for data scientists

http://www.businesscomputingworld.co.uk/

Productivity-Performance Gap

Scripting languages like Python are productive but slow and serial

Big data frameworks (Hadoop/Spark) are hard to use and slow

- High overhead runtime libraries
- Not based on parallel computing fundamentals

High performance requires low-level programming

- Not practical for interactive workflows of data scientists and their expertise

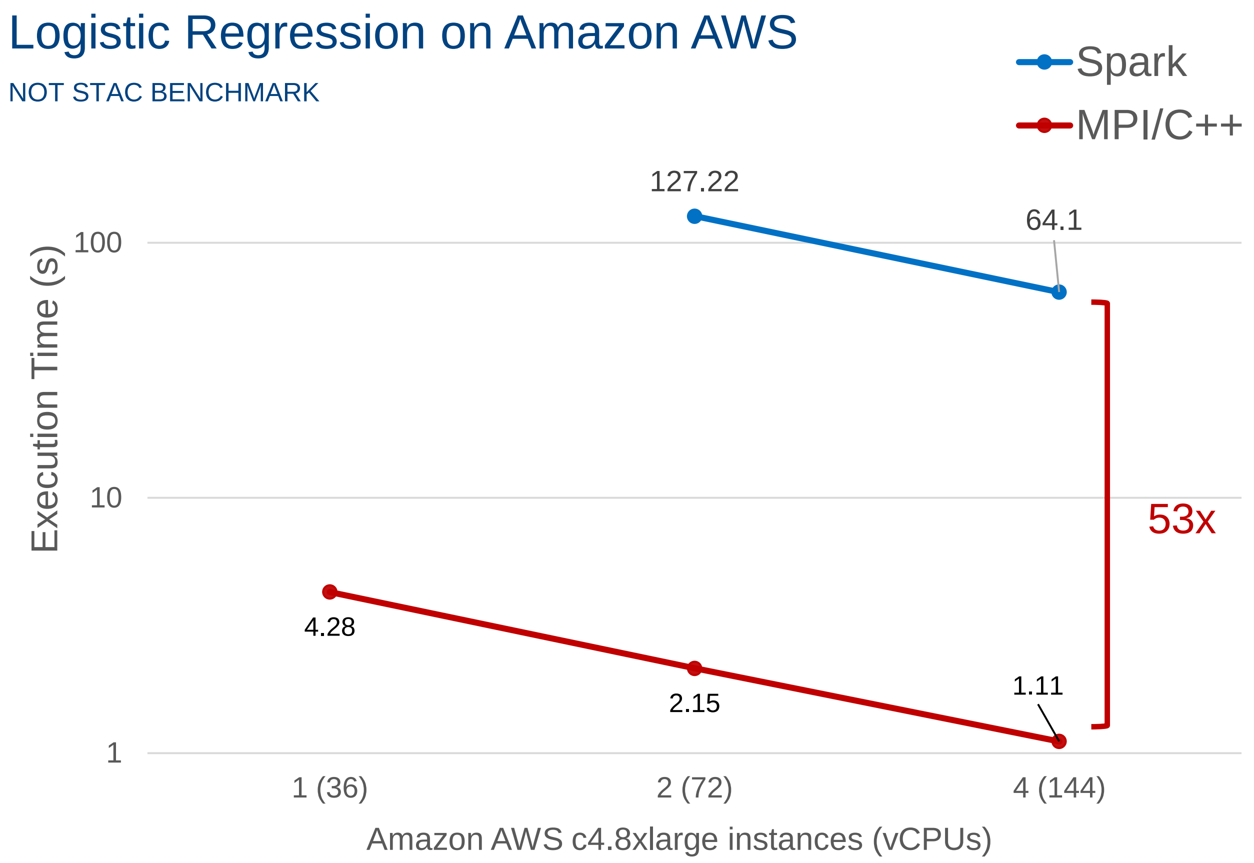
python.org

Infoobjects.com

isocpp.org

llnl.org

Motivation



Totoni et al. “A Case Against Tiny Tasks in Iterative Analytics”, *HotOS’17*

Overview

High performance/scalability for analytics/ML/AI with little effort

- Minimal changes to scripting source code

Compiler optimization and parallelization

- Scripting program → efficient parallel binary

High Performance Analytics Toolkit (HPAT)

- Python (previously Julia)

https://github.com/IntelLabs/hpat

https://github.com/IntelLabs/HPAT.jl

HPAT Python Example

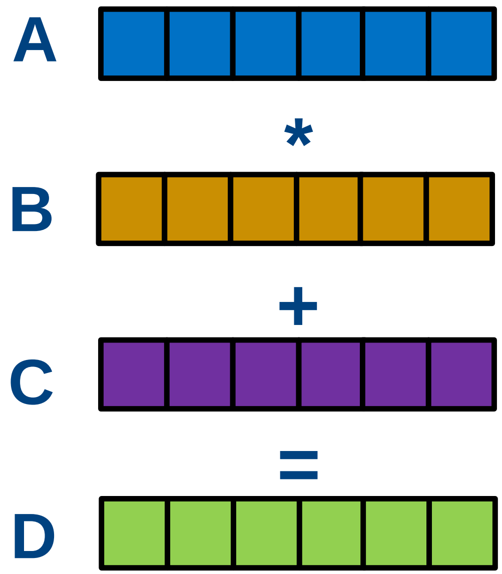
33x speedup
on 4 nodes

```
@hpat.jit
def logistic_regression(iterations):
    f = h5py.File("lr.hdf5", "r")
    X = f['points'][:]
    Y = f['responses'][:]
    D = X.shape[1]
    w = np.ones(D) - 0.5
    for i in range(iterations):
        w -= np.dot(((1.0 / (1.0 + np.exp(-Y * np.dot(X, w))) - 1.0) * Y), X)
return w
```

Numpy code is implicitly data-parallel

Example launch command:
mpirun -n 144 python logistic_regression.py

Data Parallelism Extraction




```
D = A * B + C
```

Recognize parallelism

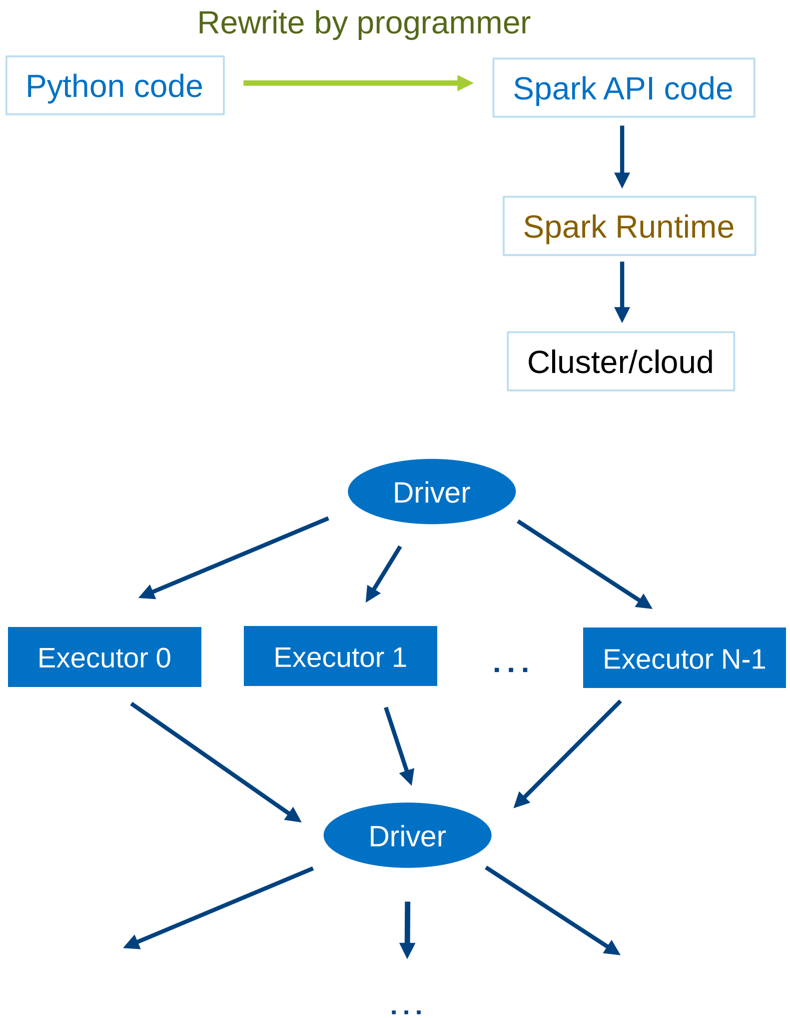
```
parfor i=1:n
    t[i]=A[i]*B[i]
parfor i=1:n
    D[i]=t[i]+C[i]
```

Fuse loops

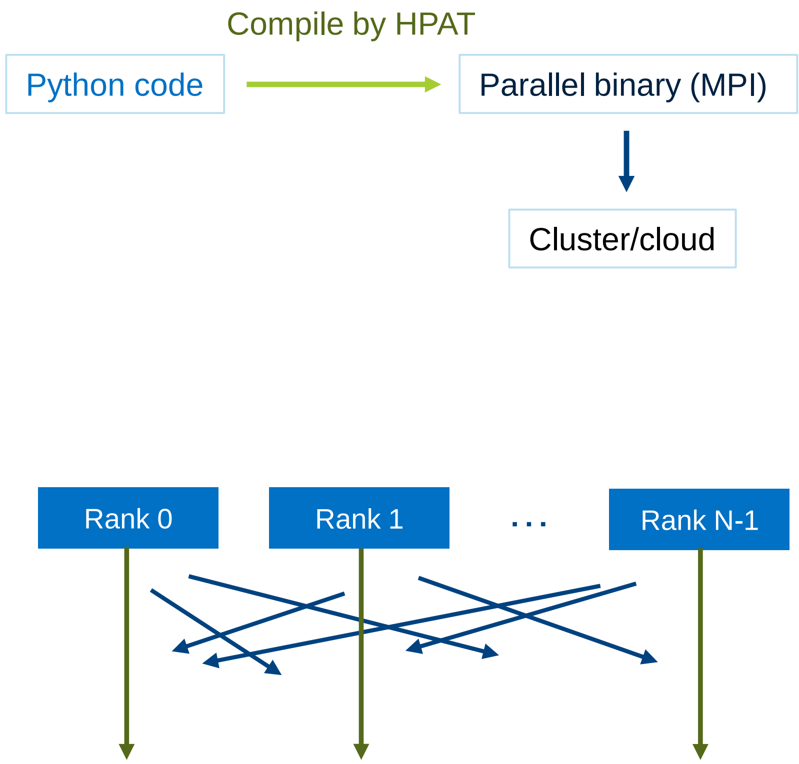
```
parfor i=1:n
    t[i]=A[i]*B[i]+C[i]
```

[1] Anderson et al. "Parallelizing Julia with a Non-invasive DSL", *ECOOP'17*

Spark Workflow



HPAT Workflow

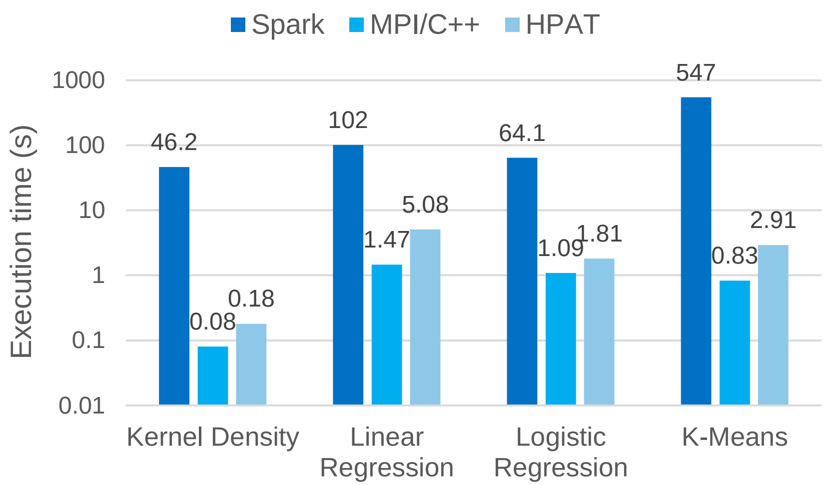


Performance Evaluation

NOT STAC BENCHMARKS

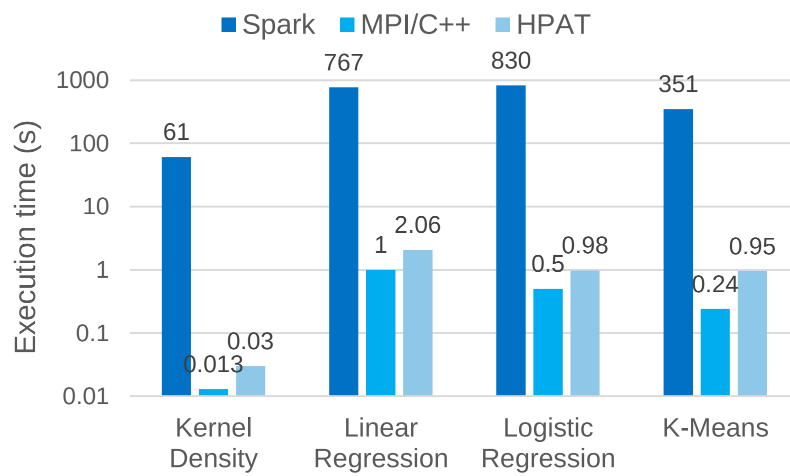
Amazon AWS
4 nodes c4.8xlarge (144 vCPUs)

20x-256x speedup of HPAT vs Spark



Cori at NERSC/LBL
64 nodes (2048 cores)

370x-2000x speedup of HPAT vs Spark



HPAT Julia used, Python will be similar

HPAT is within 2-4x MPI/C++

Totoni et al. "HPAT: High Performance Analytics with Scripting Ease-of-Use", *ICS'17*

Pandas Example

```
@hpat.jit(locals={'s_open': hpat.float64[:], …})
def intraday_mean_revert():
   f = h5py.File("stock_data.hdf5", "r"); …
   for i in prange(nsyms):
      symbol = sym_list[i]
      s_open = f[symbol+'/Open'][:]; …
      df = pd.DataFrame({'Open': s_open, …})
      df['Stdev'] = df['Close'].rolling(window=90).std()
      df['Moving Average'] = df['Close'].rolling(window=20).mean()
      df['Criteria1'] = (df['Open'] - df['Low'].shift(1)) < -df['Stdev']
      df['Criteria2'] = df['Open'] > df['Moving Average']
      df['BUY'] = df['Criteria1'] & df['Criteria2']
      df['Pct Change'] = (df['Close'] - df['Open']) / df['Open']
      df['Rets'] = df['Pct Change'][df['BUY'] == True]
      n_days = len(df['Rets'])
      res = np.zeros(max_num_days)
      if n_days:
         res[-n_days:] = df['Rets'].fillna(0)
      all_res += res
```

100x speedup on 36 cores

Explicit loop parallelism

http://www.pythonforfinance.net/2017/02/20/intraday-stock-mean-reversion-trading-backtest-in-python/

HPAT Operations

Numpy:

- Element-wise operations: +, /, ==, exp, log, sqrt, …
- Array creation: zeros, ones_like, random, normal, …
- Others: sum, prod, dot, …

Pandas:

- Column access, and operations: df.A, df['A'], df.A.std()
- Filter: df[df.A > .5]
- Rolling windows: df.A.rolling(window=5).mean()

Parallel loop:

```
for i in prange(n):
    s += A[i]**2
```

Variable Type Limitation

Input code to HPAT should be statically compilable (type stable)

- Dynamic code example:
- Rare in analytics

```
if flag1:
    a = 2
else:
    a = np.ones(n)
if isinstance(a, np.ndarray):
    doWork(a)

if flag2:
    f = np.zeros
else:
    f = np.ones
b = f(m)
```

Pandas Limitation

Data Frame column accesses should be static

- Dynamic code example:

```
for i in range(5):
    A += df['c'+str(i)]
```

- Refactor to:

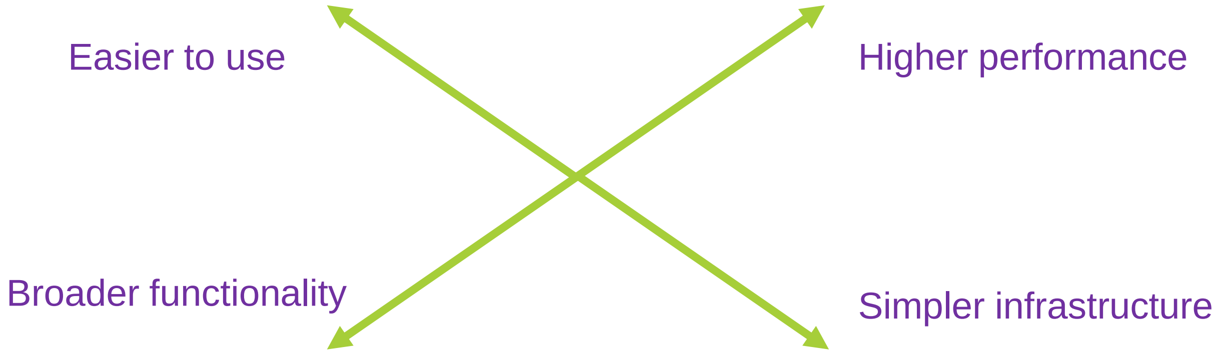
```
A += df['c0']
A += df['c1']
A += df['c2']
A += df['c3']
A += df['c4']
```

Summary

Compiler approach superior to library approach for analytics

HPAT bridges productivity-performance gap

- Compiles Python programs to efficient parallel binaries
- Available on GitHub: https://github.com/IntelLabs/hpat



References

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