Integrating Existing C++ Libraries into PySpark

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About Me

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Outline

- Why Bother – A Real-Life Use Case
- PySpark Overview
- Interfacing to Your C++ Code
- Putting It All Together
- Challenges
- C++ Tips and Tricks
- Takeaways
- Q&A

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A Real-Life Use Case

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Why Bother – A Real-Life Use Case

- Realtime system is processing news stories and giving sentiment scores – convert text to buy, sell or neutral signals on equities mentioned in it
- <10 ms response time
- Want to run the exact same code in real-time and against history

Image courtesy of https://flic.kr/p/ayDEMD

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Why Bother – A Real-Life Use Case

- Need to rerun backfill on historical data – 2 TB (compressed)
- Want to run the exact same code against history
- SLA: < 24 hours to recompute entire history
- Can do backfills for new models – monthly basis

PySpark Overview

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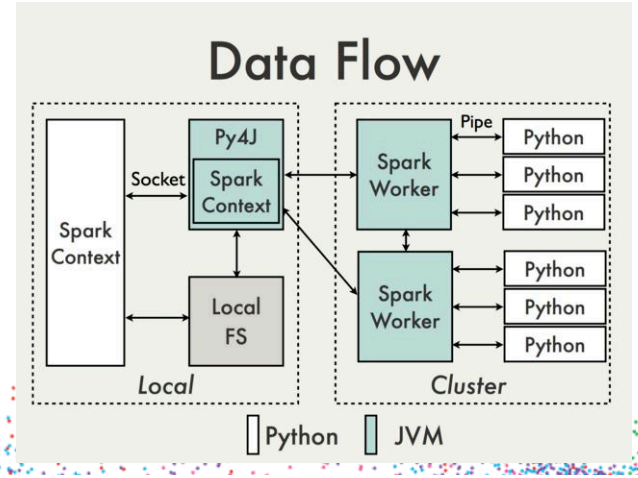
PySpark Overview

- Python front-end for interfacing with Spark system
- API wrappers for built-in Spark functions
- Allows to run any python code over the rows with User Defined Functions (UDF)
- https://cwiki.apache.org/confluence/display/SPARK/PySpark+Internals



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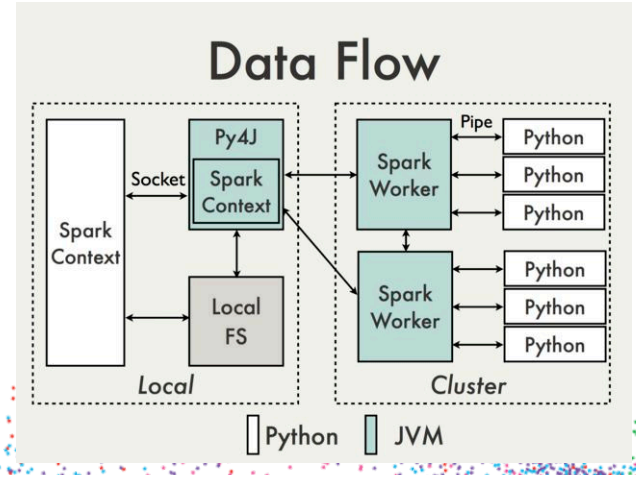
Python UDFs

- Native Python code
- Function objects are pickled and passed to workers
- Row data passed to Python workers one at a time
- Code will pass from Python runtime-> JVM runtime -> Python runtime and back
- [SPARK-22216] [SPARK-21187] – support vectorized UDF support with Arrow format – see Li Jin's talk



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Interfacing to your C++ Code

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Interfacing to your C++ Code with PySpark

	Pros	Cons
SWIG	• Very powerful and mature • supports classes and nested types • Language-agnostic – can use with JNI	• Complex • Requires extra .ini file • Extra step before linking
Cython	• Don't need extra files • Very easy to get started • Speeds up python code	• intricate build • separate install
ctypes	• Don't need extra files • Very easy to get started	• Limited types available • tedious
CFFI	• easy to use and integrate	• PyPy focused • new, changes quickly

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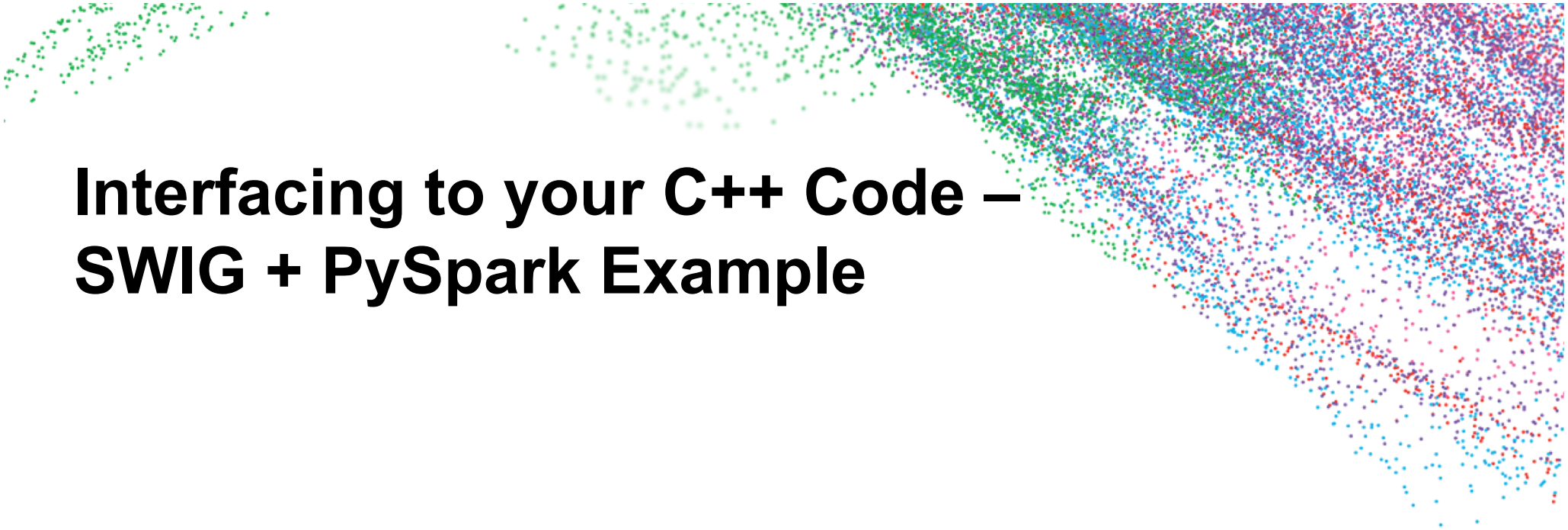
Interfacing to your C++ Code via the JVM

	Pros	Cons
JNI	• Skips the extra Python wrapper step – straight to JVM space (e.g., Spark ML Blas implementation using nettlib)	• Clunky, difficult to maintain
SWIG	• Very powerful and mature • supports classes and nested types • Language-agnostic • Run over JNI	• Very powerful and mature • supports classes and nested types • Language-agnostic
Scala pipe() command	• Use a pipe() call to interface with your C++ code using a system call and stdin/stdout	• Very brittle



Interfacing to your C++ Code – SWIG + PySpark Example

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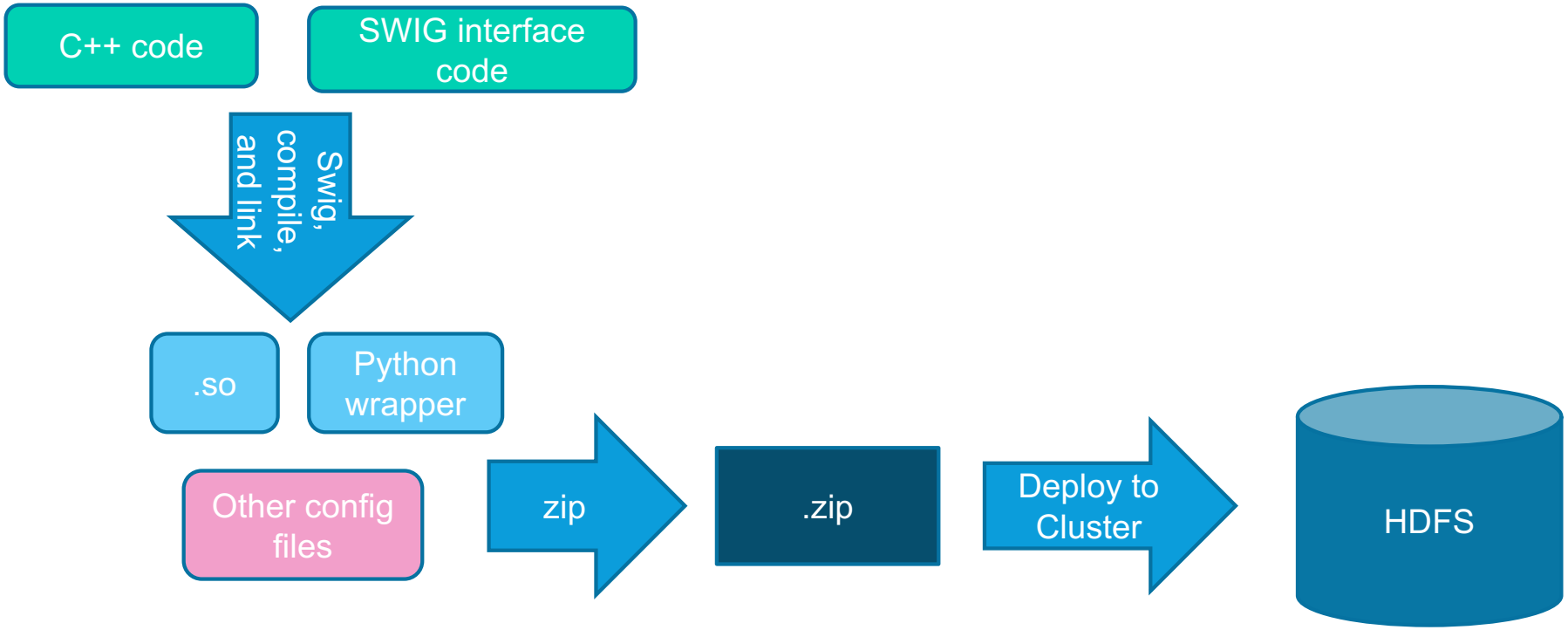
Why SWIG + PySpark Example

- SWIG wrapper was already written
- Maintenance – institutional knowledge dictated the choice of Python
- Back-end work, less concerned with exact time it takes to run
- Final run took ~24 hours

SWIG Workflow



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SWIG Example

- Start with simple SWIG interface – adapted from (http://www.swig.org/tutorial.html)

```
/* File : example.c */
int my_mod(int x, int y) { return x%y; }
```

```
 /* example.i */
 %module example
 %{
 /* Put header files here or function declarations like below */
 extern int my_mod(int x, int y);
 %}

 extern int my_mod(int x, int y);
```


SWIG Example continued

- Create the C++ and Python wrappers

```
$ swig -python example.i
```

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SWIG Example continued

- Create the C++ and Python wrappers

```
$ swig -python example.i
```

- Compile and link

```
$ gcc  -fPIC -c example.c example_wrap.c  \
-I/usr/local/include/python2.7
$ld -shared example.o example_wrap.o -o _example.so
```


SWIG Example continued

- Create the C++ and Python wrappers

```
$ swig -python example.i
```

- Compile and link

```
$ gcc  -fPIC -c example.c example_wrap.c \
-I/usr/local/include/python2.7
$ld -shared example.o example_wrap.o -o _example.so
```

- Test the wrapper

```
>>> import example
>>> example.my_mod(7, 3)
1
```


SWIG Example continued

- Now wrap into a zip file that can be shipped to the Spark cluster

```
$ zip example.zip _example.so example.py
```

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SWIG Example – PySpark program

```
def calculateMod7(val):
        sys.path.append('example')
        import example
        return example.my_mod(val, 7)
```

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SWIG Example – PySpark program

```
def calculateMod7(val):
        sys.path.append('example')
        import example
        return example.my_mod(val, 7)

def main():
        spark = \
              SparkSession.\
              builder.appName('testexample')\
              .getOrCreate()
        df = spark.read.parquet('input_data')
        calcmod7 = udf(calculateMod7, IntegerType())
        dfout = df.limit(10).withColumn('calc_mod7',\
       calcmod7(df.inputcol)).select('calc_mod7')
        dfout.write.format("json").mode("overwrite").save('calcmod
7')

if __name__ == "__main__":
    main()
```

Main run in the driver

Read

Wrap UDF

Add column to dataframe with UDF output

Write output to HDFS

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SWIG Example – spark-submit

```
spark-submit --master yarn  --deploy-mode cluster --archives
example.zip#example –conf \
"spark.executor.extraLibraryPath:./example" testexample.py
```

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SWIG Example – Environment Variable

- Make a mod based on an environment variable (don't really write code like this!)

```
/* File : example2.c */
#include <stdlib.h>
int my_mod(int x) {
    return x%atoi(getenv("MYMODVAL"));
}
```

```
 /* example2.i */
 %module example2
 %{
 /* Put header files here or function declarations like below */
 extern int my_mod(int x);
 %}

 extern int my_mod(int x);
```


SWIG Example with Environment Variable

```
def calculateMod(val):
        sys.path.append('example2')
        import example2
        return example2.my_mod(val)

def main():
        spark = \
             SparkSession.\
             builder.appName('testexample')\
             .getOrCreate()
        df = spark.read.parquet('input_data')
        calcmod = udf(calculateMod, IntegerType())
        dfout = df.limit(10).withColumn('calc_mod',\
       calcmod(df.inputcol)).select('calc_mod')
        dfout.write.format("json").mode("overwrite").save('calcmod
')

if __name__ == "__main__":
    main()
```

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SWIG Example with Environment Variable

```
spark-submit --master yarn  --deploy-mode cluster --archives
example2.zip#example2 --conf
"spark.executor.extraLibraryPath:./example2" --conf
"spark.executorEnv.MYMODVAL=7" testexample2.py
```

Note – this only sets the environment variable on the driver, not the executor

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SWIG Example – PySpark program – Efficiency Attempt

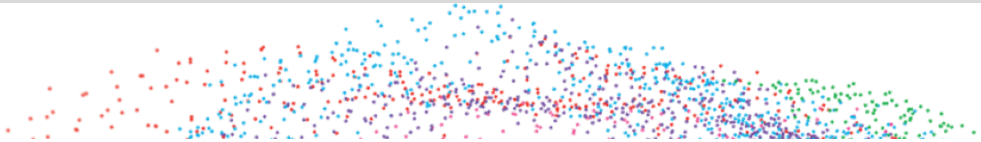
```
sys.path.append('example')
import example
def calculateMod7(val):
       return example.my_mod(val, 7)

def main():
        spark = \
              SparkSession.\
              builder.appName('testexample')\
              .getOrCreate()
        df = spark.read.parquet('input_data')
        calcmod7 = udf(calculateMod7, IntegerType())
        dfout = df.limit(10).withColumn('calc_mod7',\
       calcmod7(df.inputcol)).select('calc_mod7')
        dfout.write.format("json").mode("overwrite").save('calcmod
7')

if __name__ == "__main__":
    main()
```

SWIG Example – Efficiency Attempt – FAIL!

```
  command = serializer._read_with_length(file)
  File
"/disk/6/yarn/local/usercache/eiserov/appcache/application_1524013
228866_17087/container_e141_1524013228866_17087_01_000009/pyspark.
zip/pyspark/serializers.py", line 169, in _read_with_length
    return self.loads(obj)
  File
"/disk/6/yarn/local/usercache/eiserov/appcache/application_1524013
228866_17087/container_e141_1524013228866_17087_01_000009/pyspark.
zip/pyspark/serializers.py", line 434, in loads
    return pickle.loads(obj)
  File
"/disk/6/yarn/local/usercache/eiserov/appcache/application_1524013
228866_17087/container_e141_1524013228866_17087_01_000009/pyspark.
zip/pyspark/cloudpickle.py", line 674, in subimport
    __import__(name)
ImportError: ('No module named example', <function subimport at
0x7fbf173e5c80>, ('example',))
```



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Challenges – Efficiency

- UDFs are run on a per-row basis
- All function objects passed from the driver to workers inside the UDF needs to be able to be pickled
- Most interfaces can't be pickled
- If not, would create on the executor, row by row

Solutions:

- Do not keep state in your C++ objects
- Spark 2.3 – use Apache Arrow on vectorized UDFs
- Use Python Singletons for state
- df.mapPartitions()

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Using mapPartitions Example

```
class Partitioner:
   def __init__(self):
        self.callPerDriverSetup
   def callPerDriverSetup(self):
        pass
   def callPerPartitionSetup(self):
        sys.path.append('example')
        import example
        self.example = example
   def doProcess(self, element):
        return self.example.my_mod(element.wire, 7)
   def processPartition(self, partition):
        self.callPerPartitionSetup()
        for element in partition:
                yield self.doProcess(element)
```

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Using mapPartitions Example Cont'd

```
def main():
        spark = \
             SparkSession.\
             builder.appName('testexample')\
             .getOrCreate()

        df = spark.read.parquet(input')
        p = Partitioner()
        rddout = df.rdd.mapPartitions(p.processPartition)
        ...

if __name__ == "__main__":
    main()
```

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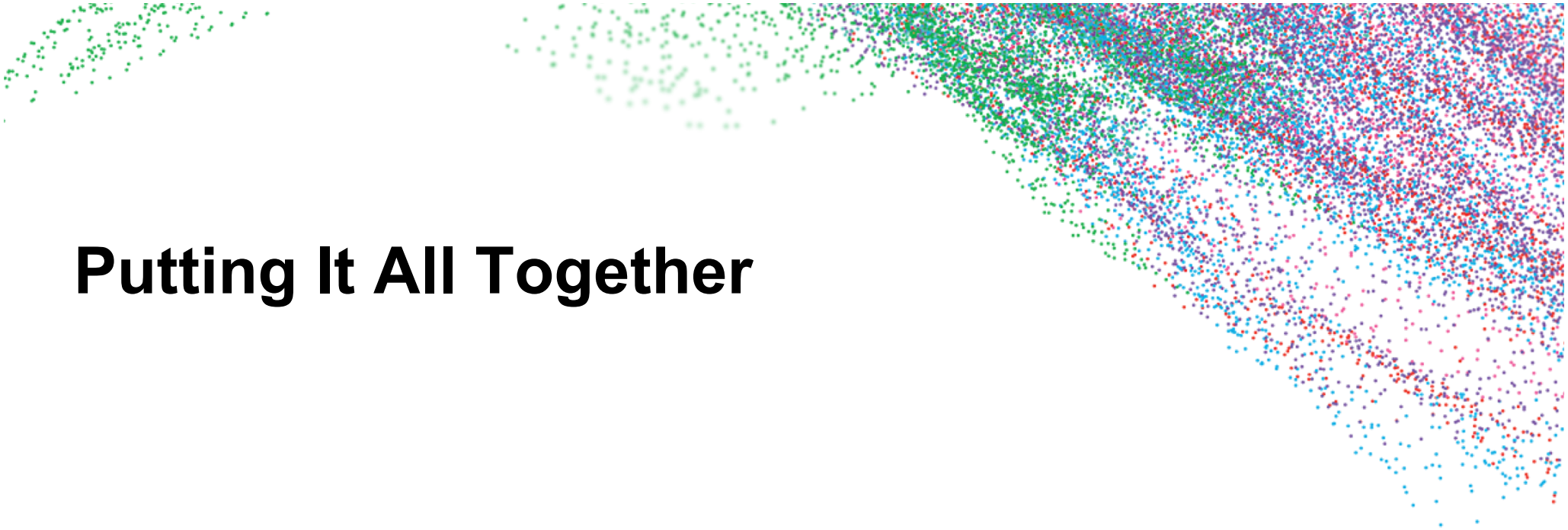

Putting It All Together

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Putting It All Together

- Create .so of your C++ code
- Ensure your compiler toolchain matches that of Spark cluster
- Make .so available on the cluster
  - Deploy to all cluster machines
  - Deploy to known location on HDFS
  - Include any necessary config files
  - May need to include dependent libs if not on the cluster
- Pass environment variables to drivers and executors

Putting It All Together

Variable passed	Set To	Purpose
`spark.executor.extraLibraryPath`	append new path where .so was deployed to	Ensure C++ lib is loadable
`spark.driver.extraLibraryPath`	append new path where .so was deployed to	Ensure C++ lib is loadable
`--archives`	.zip or .tgz file that has your .so and config files	Distributes the file to all worker locations
`--pyfiles`	.py file that has your UDF	Distributes your udf to workers. Other option is to have it directly in your .py that you call spark-submit on
`spark.executorEnv.<ENVIRONMENT_VARIABLE>`	Environment variable value	If your UDF code reads environment variables
`spark.yarn.appMasterEnv. .<ENVIRONMENT_VARIABLE>`	Environment variable value	If your driver code reads environment variables

Putting It All Together

```
$ spark-submit  --master yarn  --deploy-mode cluster
--conf "spark.executor.extraLibraryPath=<path>:myfolder"
--conf "spark.driver.extraLibraryPath =<path>:./myfolder"
--archives myfolder.zip#myfolder
--conf "spark.executorEnv.MY_ENV=my_env_value"
--conf "spark.yarn.appMasterEnv.MY_DRIVER_ENV=my_driver_env_value"
my_pyspark_file.py
<add file params here>
```

Run spark-

Set library path on the executor

Set library path on the driver

Pass your .so and other files to the executors

Set the executor

Set the driver environment variables

Pass parameters to your PySpark code here

Pass your PySpark code

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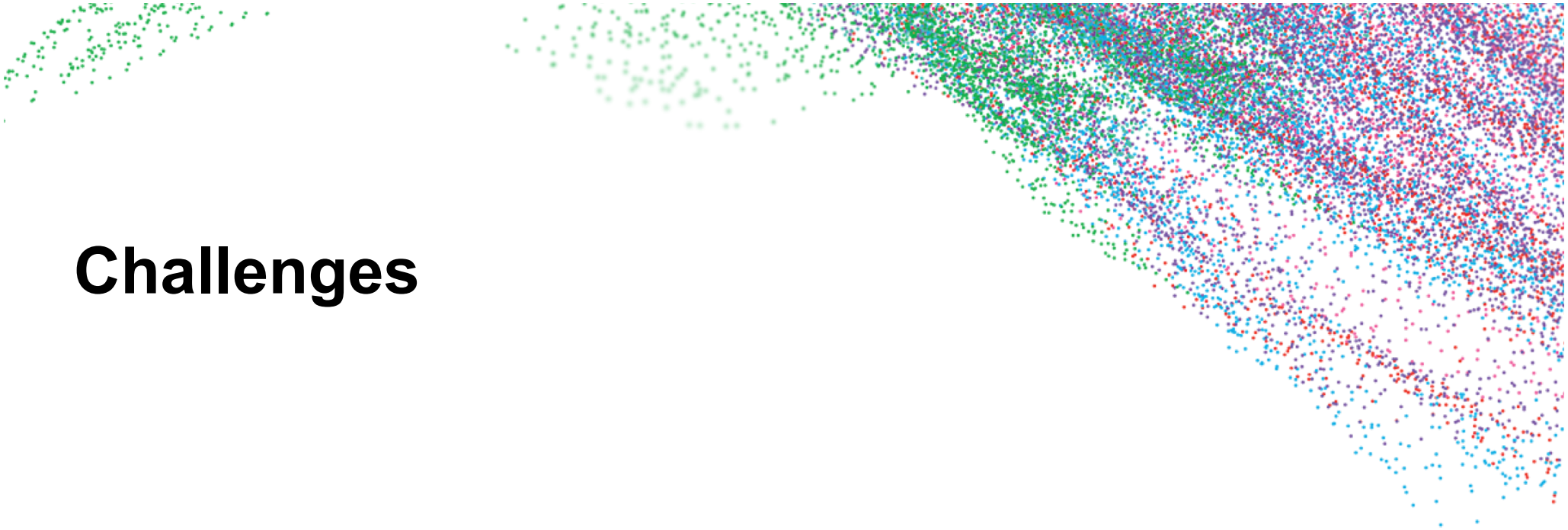

Challenges

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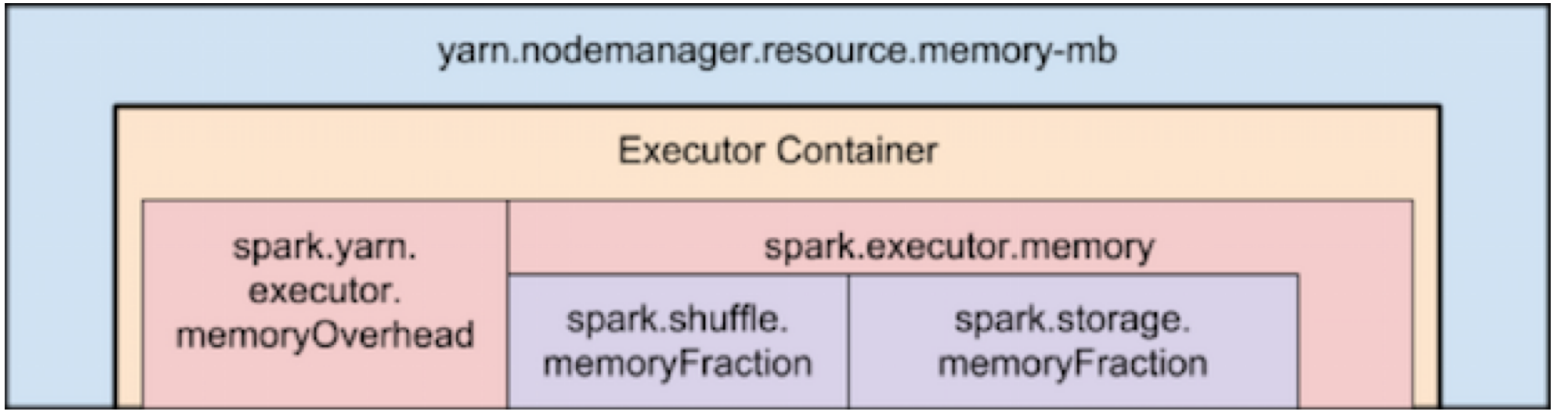
Challenges – Memory

- Spark sets number of partitions heuristically, may not be efficient
- Ensure you have enough memory in your YARN python container to load your .so and its config files
- https://blog.cloudera.com/blog/2015/03/how-to-tune-your-apache-spark-jobs-part-2/



Memory Settings

- Explicitly set partitions
  - Either when reading in file or
  - df.repartition(num_partitions)

- Allocate more memory to drivers explicitly:

```
$ spark-submit --executor-memory 5g --driver-memory 5g --conf
"spark.yarn.executor.memoryOverhead=5000"  --conf
```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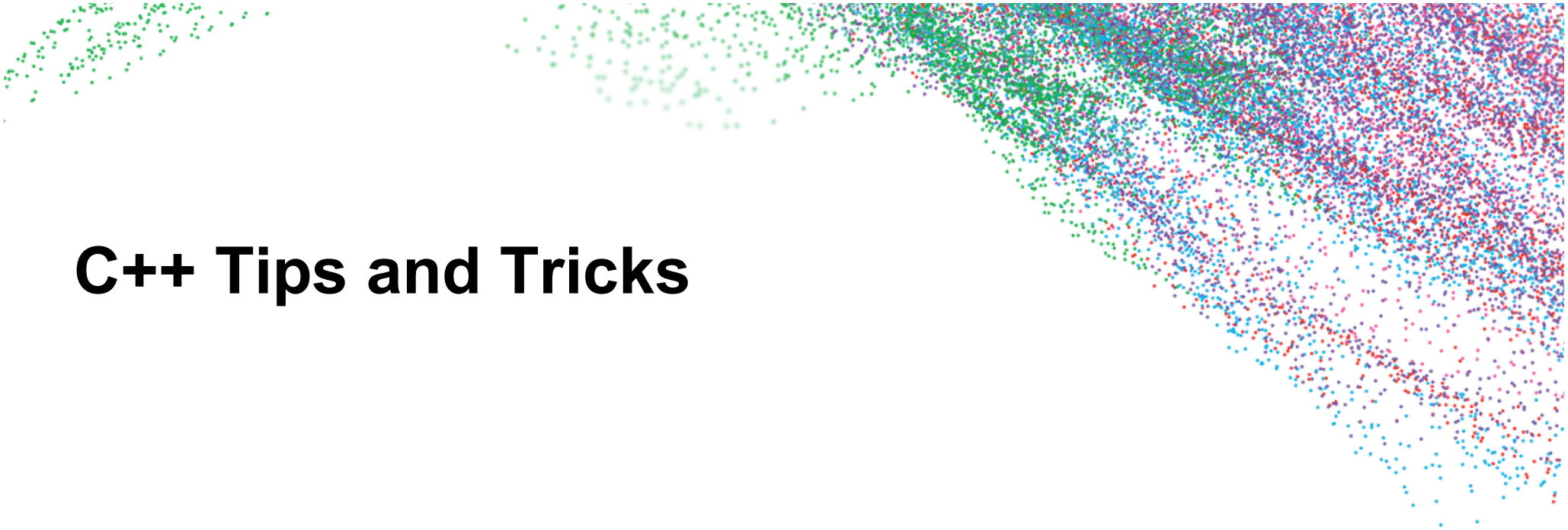

C++ Tips and Tricks

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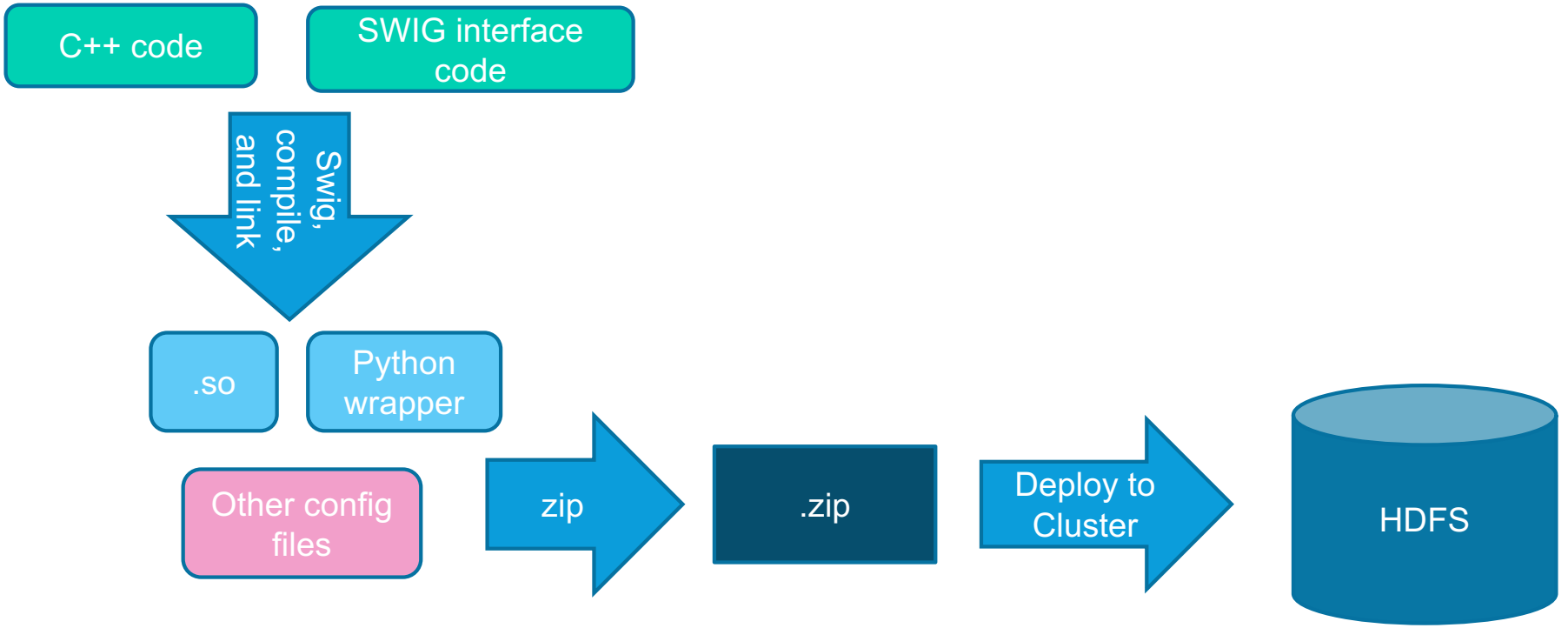
Development & Deployment Review



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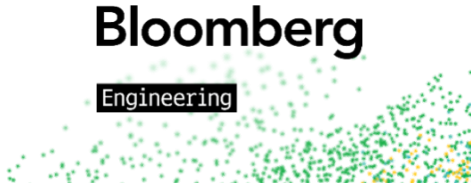
C++ Tips and Tricks

- Goals:
  - Want to minimize changing the Python/C++ API interface
  - Want to avoid recompilation and deployment

- Tips
  - Flexible templatized interface
  - Bundle config file with .so for easier deployment



Conclusion

- Was able to run backfill of all data on existing models in <24 hours
- Was able to generate backfills on new models iteratively

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Takeaways

- Spark is flexible enough to include C++ code
- Deploy all dependent code to cluster
- Tweak spark-submit commands to properly pick it up
- Write flexible C++ code to minimize overhead

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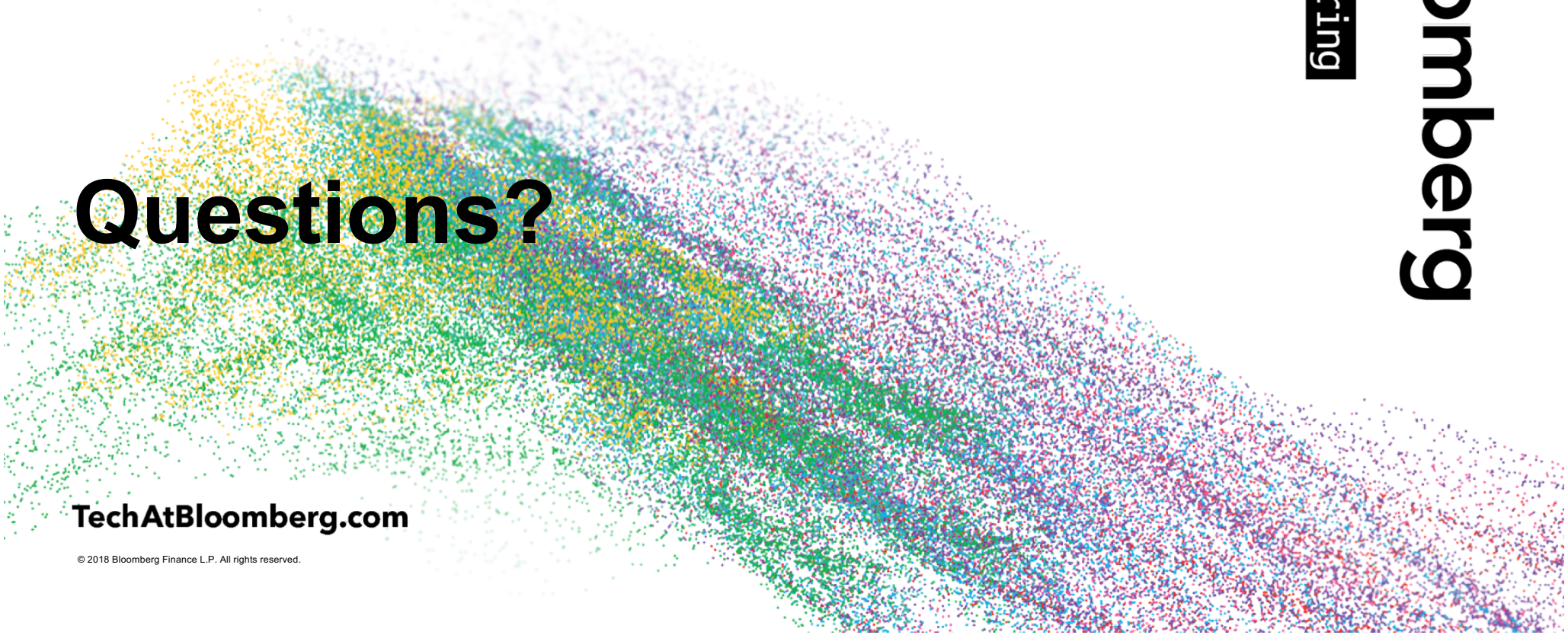

Questions?

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