Integrating Multi-Party Computation in Big Data Workflows

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How often does ‘#@%!’ appear in the internal chat logs of these companies?
Sounds like a job for hadoop

We’re talking Terabytes of data ⇒ a Python script won’t cut it.

Mode of operation: distribute data across many machines, process in parallel.

Programming paradigm: specify data analytics tasks in high-level language.

Backend infrastructure: cluster of machines.
Gimme all your data!
Multiparty computation (MPC) is a crypto tool for privacy preserving computation.
So much MPC!
So our data analyst should use MPC right?
Great in theory **but...**

**Accessibility.** MPC frameworks have a steep learning curve and don’t provide the high-level representations that data analysts use.

**Scalability.** MPC is slow.

**Bottom line:**

Our analyst probably doesn’t know MPC, or how to use it.

Any MPC framework is **far** too slow to process GBs of data.
What about a *hybrid* approach?

```
logs_a
  count(#@$%)
    count_a

logs_b
  count(#@$%)
    count_b

logs_c
  count(#@$%)
    count_c
```

```
sum() -> MPC -> 9001!
```
A lot of work and expert knowledge required

- logs_a
  - count(#@$%)
  - count_a

- logs_b
  - count(#@$%)
  - count_b

- logs_c
  - count(#@$%)
  - count_c

\(sum()\) → MPC → 9001!
Good news!

We have just the system for you:

- Relational front-end language to specify workflow
- Automatic detection of which part of the workflow requires MPC
- Automatic code generation and execution
- Directive: “Do as much locally as possible.”
- Leverages existing frameworks as backends
The main components of our system

**SQL-like programming language** to specify analytics using standard relational operators.

**Compiler** that converts programs to jobs that are executable in existing data processing frameworks and MPC frameworks.

**Dispatcher** to execute the generated jobs automatically and seamlessly on the available backends.
Let’s explore top-down

**SQL-like programming language** to specify analytics using standard relational operators.

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**Dispatcher** to execute the generated jobs automatically and seamlessly on the available backends.
This is what the analyst writes

```sql
select count(log_message) 
  from logs 
where log_message like '#@$%';
```

I’ll pretend I have all the data.
The main components of our system

**SQL-like programming language** to specify analytics using standard relational operators.

**Compiler** that converts programs to jobs that are executable in existing data processing frameworks and MPC frameworks.

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Relational

```sql
select count(msg) 
  from logs 
where msg like '#@$%';
```
Relational $\Rightarrow$ IR

```
select count(msg)
  from logs
where msg like '#@$%';
```
Relational $\Rightarrow$ IR $\Rightarrow$ MPC-IR

```sql
select count(msg)
  from logs
where msg like '#@$%';
```
We don’t need MPC for selections

```
select count(msg)
from logs
where msg like '#@$%';
```
But what about aggregations?

```sql
select count(msg)
  from logs
where msg like '#@%';
```
count(whole) = sum(count(parts))

```sql
select count(msg)
from logs
where msg like '#@$%';
```
Relational $\Rightarrow$ IR $\Rightarrow$ MPC-IR

\begin{align*}
\text{select} & \quad \text{count}(\text{msg}) \\
\text{from} & \quad \text{logs} \\
\text{where} & \quad \text{msg} \ \text{like} \ ' #@$%';
\end{align*}
Relational $\Rightarrow$ IR $\Rightarrow$ MPC-IR $\Rightarrow$ Partitions

```sql
select count(msg)
from logs
where msg like '#@$%';
```
Relational ⇒ IR ⇒ MPC-IR ⇒ Partitions ⇒ Backends

```sql
select count(msg) 
from logs 
where msg like '#@$%';
```
The main components of our system

A **SQL-like programming language** to specify analytics using standard relational operators.

A **Compiler** that converts programs to jobs that are executable in existing data processing frameworks and MPC frameworks.

A **Dispatcher** to execute the generated jobs automatically and seamlessly on the available backends.
The baseline

- SQL
- VIFF
- SQL
- SQL
- hadoop
- hadoop
Our system compiles programs into jobs
The subtasks are dispatched to the available backends and executed there.
The MPC step involves delivering data to the MPC service.
Executing the analytics on the secret data
And finally retrieving the results
Okay, but did you actually count swear words?

^%::&++!
Herfindahl-Hirschman Index

A measure of market concentration.

The sum of squares of a market shares.
## Market concentration of NYC cab trip data

<table>
<thead>
<tr>
<th>Setup</th>
<th>Data Volume</th>
<th>Runtime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insecure, trusted Hadoop (8 nodes)</td>
<td>156 GB</td>
<td>16 min 10 s (970s)</td>
</tr>
<tr>
<td><strong>Our system with MPC</strong> (5 parties, 1+1+1+1+4 nodes)</td>
<td>{16,16,16,28,80} GB</td>
<td>17 min 31 s (1,051s)</td>
</tr>
<tr>
<td>MPC framework only (VIFF, 5 parties, 5 nodes)</td>
<td>156 GB</td>
<td>&gt;2 hours (&gt;7,200s)</td>
</tr>
</tbody>
</table>
Implementation

We extended Musketeer, a big data workflow manager, to incorporate MPC.
Future directions

- **Ownership provenance**
- More MPC backends!
- Multiple MPC backends in single workflow
- Repeated MPC (iterative/separate cliques)
Select → Project → Sum → Join → Max → Project → Min
Future directions

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- More MPC backends!
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- Ownership provenance
- More MPC backends!
- Multiple MPC backends in single workflow
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Summary

SQL-like programming language to specify analytics using relational operators.
⇒ No MPC experience required!

Compiler detects MPC boundaries, converts programs to parallel data processing and MPC jobs, and generates code for individual jobs.
⇒ No manual implementation required.

Dispatcher executes the generated jobs automatically on the available backends, choosing the best strategy.
⇒ No new infrastructure or “glue scripts” required.