SemTech 2010 Presentation

# Semantics in the Cloud

## Scalable Distributed Computing for the Semantic Web and the SHARD Triple-Store

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Gail Mitchell, Doug Reid from BBN
Hanspeter Pfister from Harvard SEAS
Prakash Manghwani

Raytheon
BBN Technologies

# Why?

- Triple-Store Study:
  - “An Evaluation of Triple-Store Technologies for Large Data Stores”, SSWS '07 (Part of OTM)
  - Great help from OntoText, Franz
- Design Goals (not just scalability!):
  - Scalable – avoid monolithic resource limitations.
  - High Assurance – maintain QoS despite major failures.
  - Cost Effective – only commodity hardware.
  - Modular – strong data separation to maintain provenance

# Cloud/Grid/Utility Computing?

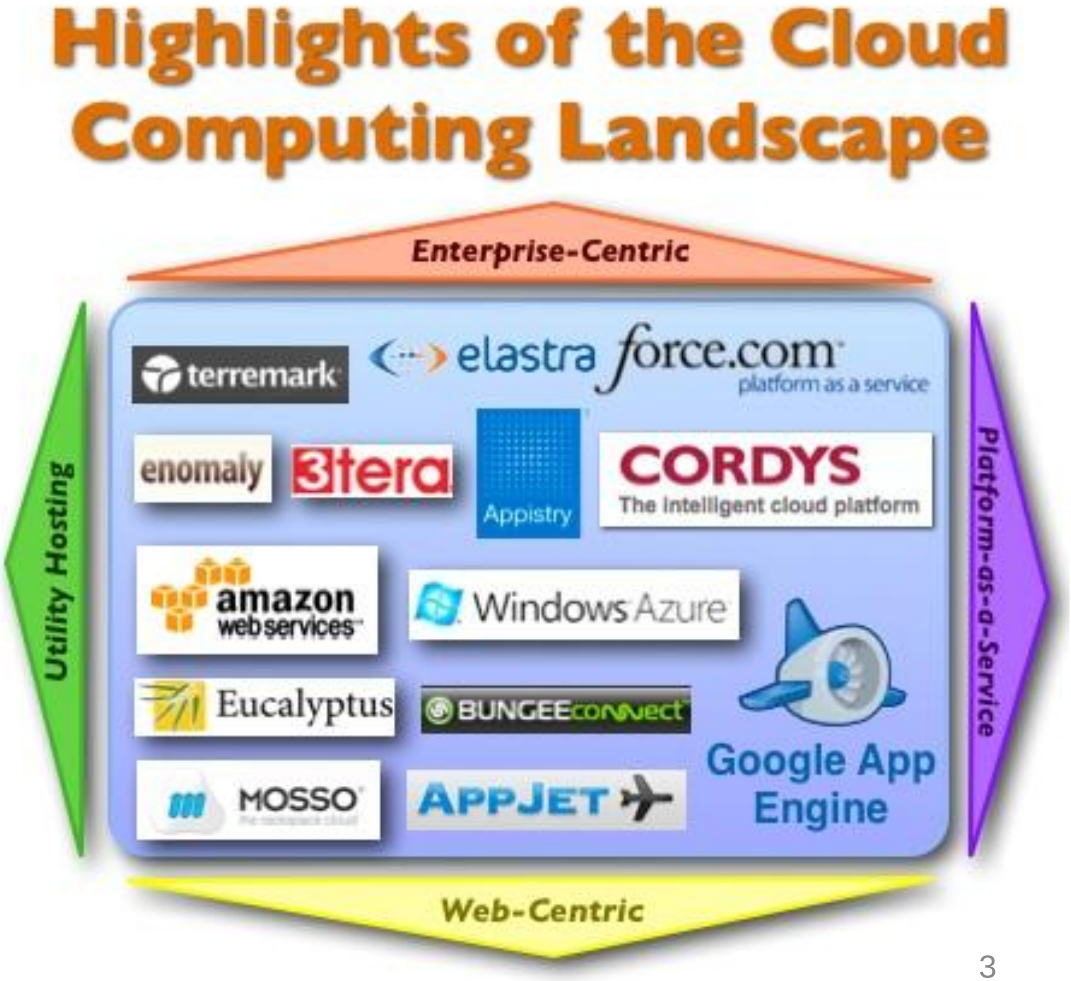
- Cloud computing means different things depending on where you play in the stack:
  - Services:

    *PayPal, Google Search*
  - Solutions:

    *Google App Engines*
  - Storage:

    *Rackspace Cloud Files*
  - Infrastructure:

    *Amazon EC2*



From http://blogs.zdnet.com/Hinchcliffe

# A Map-Reduce Implementation

- Open implementation of Google’s tech.
  - Developed from Google publications.
  - Heavily pushed by Yahoo, Facebook, etc…

  http://hadoop.apache.org/
- Cloudera has great training material
  - Look for VMWare training virtual machine

  http://www.cloudera.com/

# Some Big Numbers

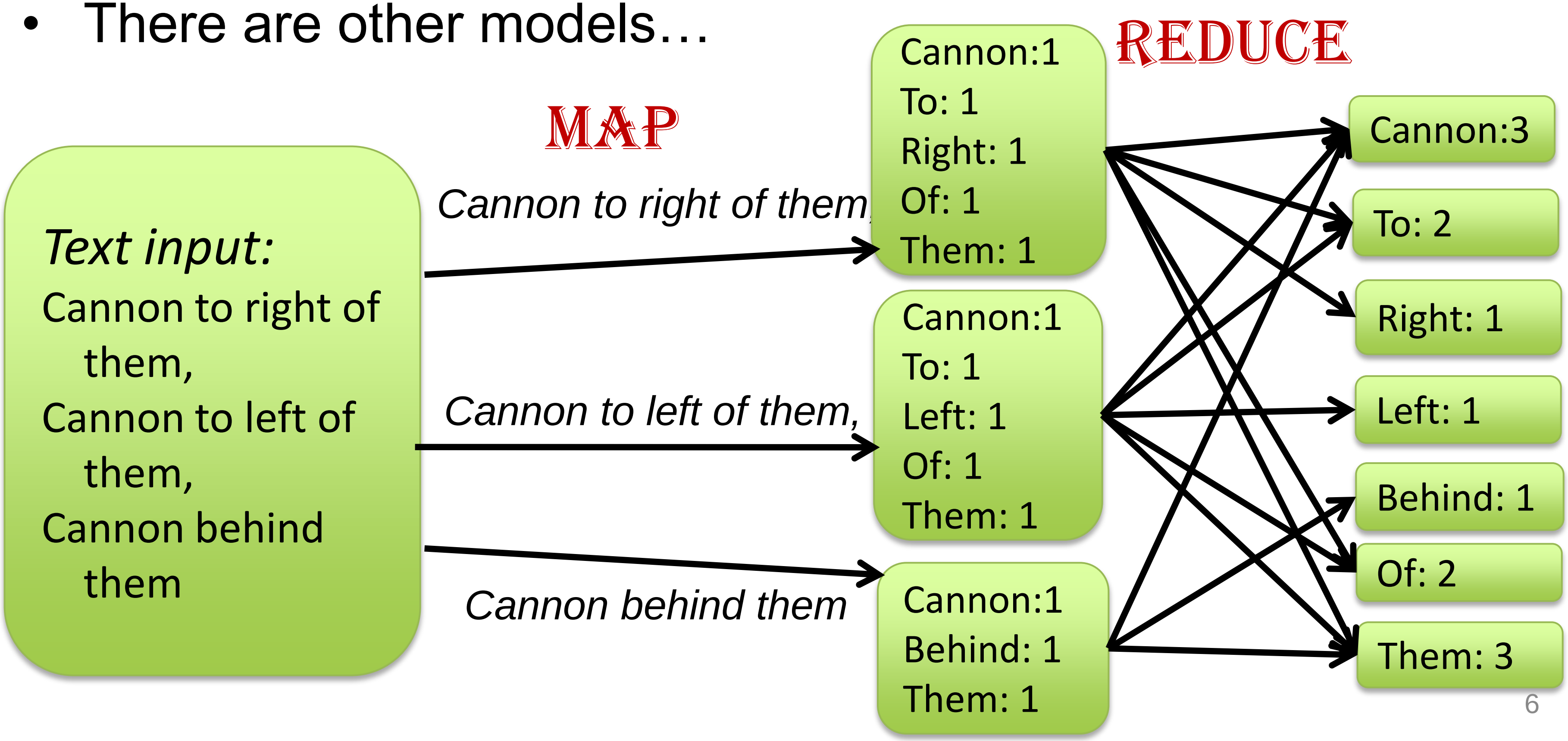
- Yahoo! Hadoop Clusters: > 82PB, >25k machines (HadoopWorld NYC ’09)
- Google: 40 GB/s GFS read/write load (Jeff Dean, LADIS ’09) [~3,500 TB/day]
- Facebook: 4TB new data per day; DW: 4800 cores, 5.5 PB (Dhruba Borthakur, HadoopWorld)

# Map-Reduce, Functionally

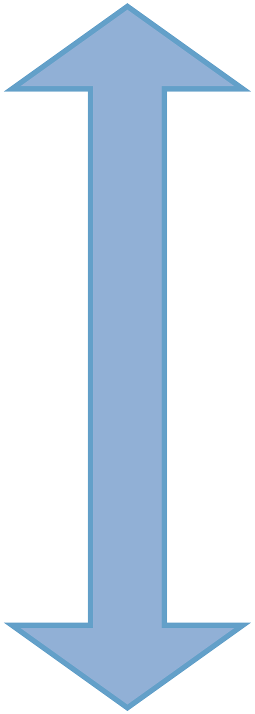
- A cloud computing model
- 2 epochs, each run concurrently over many machines:

  Map: split each input line into little pieces of data

  Reduce: recombine little pieces
- There are other models…



# New Datastore Models



- File System

  (HDFS: Hadoop Dist. File System)
- Flat Files
- Bigtable, Dynamo, Cassanda, ...
- Triple-Stores
- Database

# General Programming of These Systems...

From Experience:

- Inherently multi-threaded
- Toolset still young
  - Not many debugging tools
- Mental models are different...
  - Learn an algorithm, adapt it to M/R

# Map-Reduce Triple-Store Proof of Concept

# SHARD Triple-Store

SemWeb Triple Store Built on Hadoop

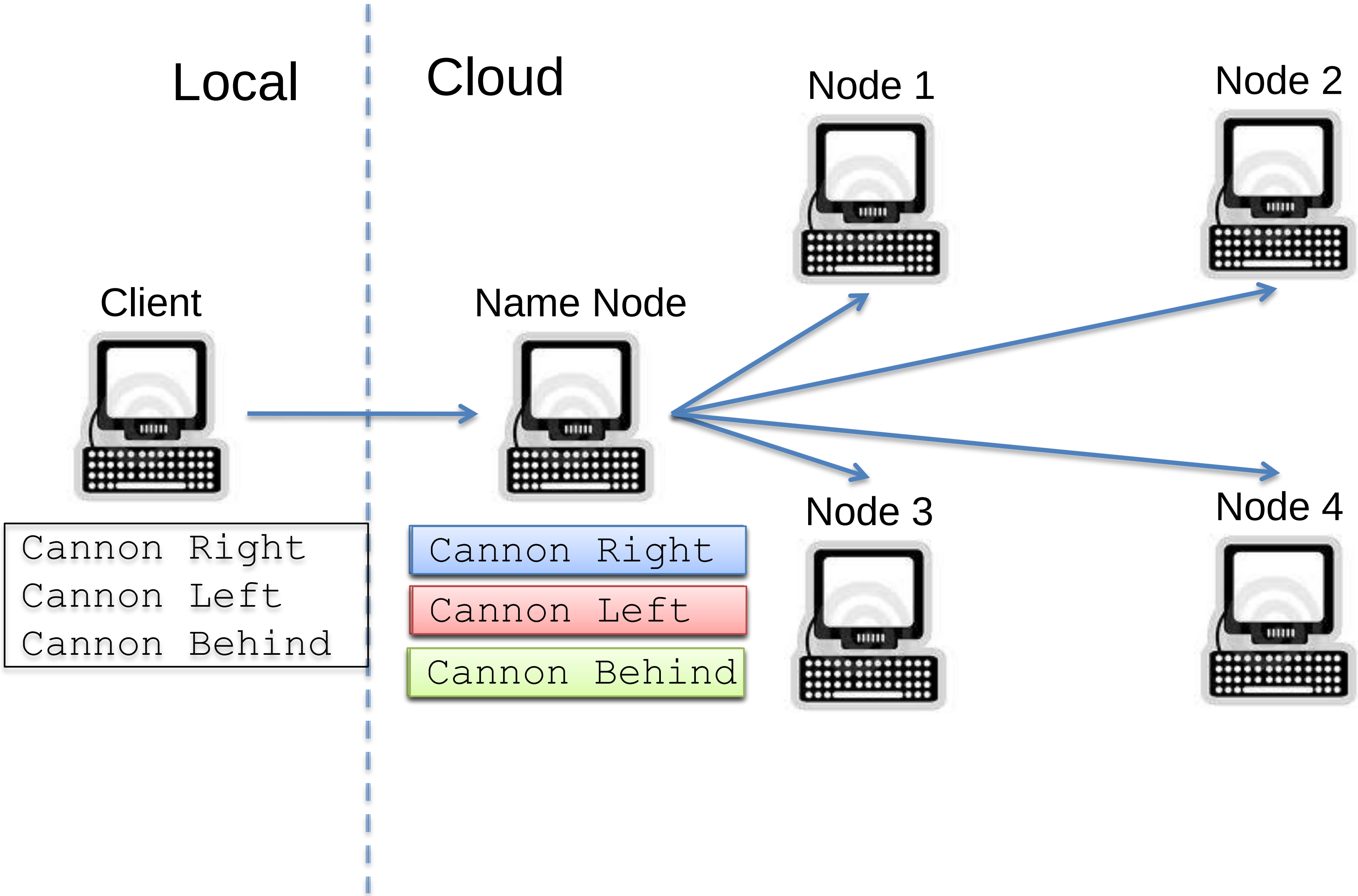
Design Goals:

- Scalable
- Robust
- Commodity Hardware

# More Specifically

- Cloud-based triple-store on HDFS
  - Massively scalable
- SPARQL queries
  - LUBM proof-of-concept
- Basic inferencing
  - subClassOf, subPropertyOf
- Java API
  - Method calls at client
  - Processing in cloud
  - Move results to local machine

# HDFS, Physically



Local

Cloud

Node 1

Node 2

Client

Name Node

Node 3

Node 4

```
Cannon Right
Cannon Left
Cannon Behind
```

Cannon Right

Cannon Left

Cannon Behind

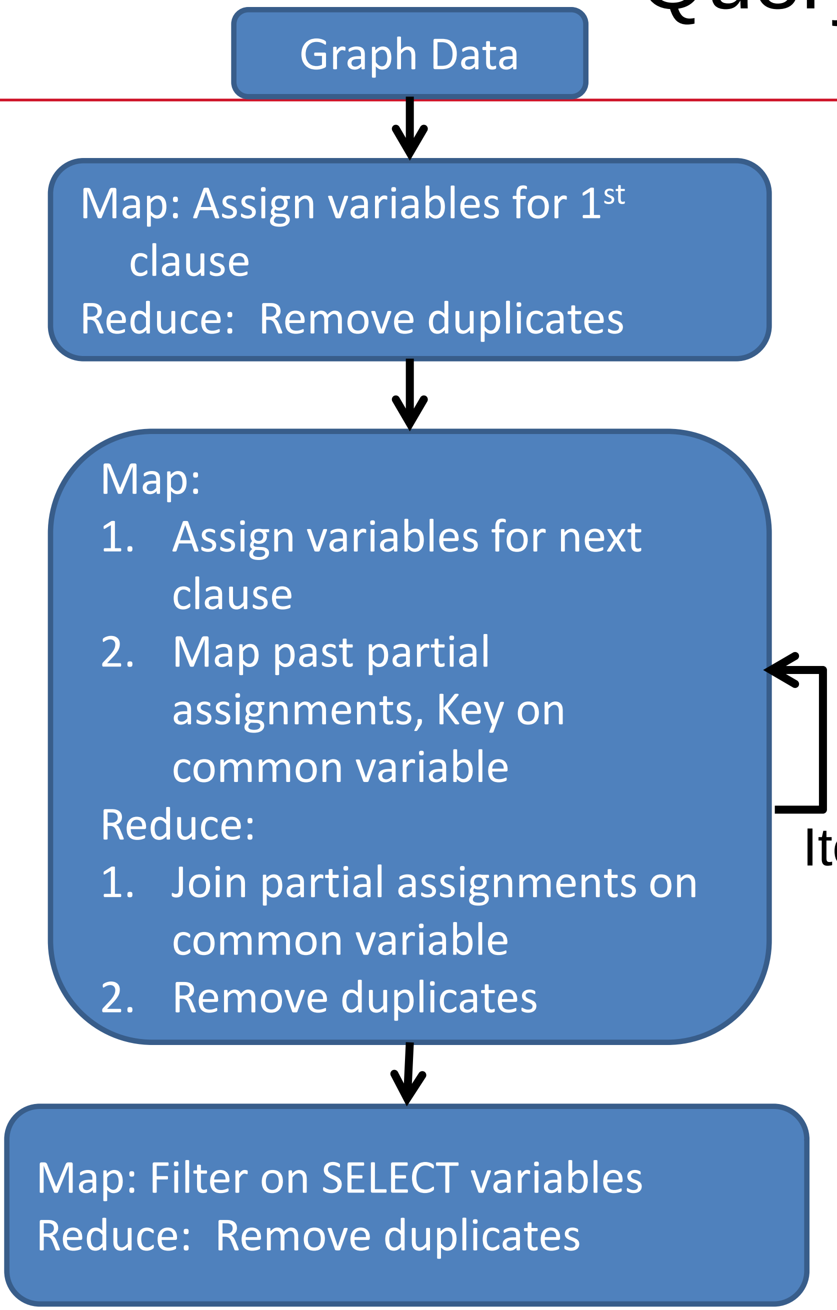
# Robustness?

- Datanode crash?
  - Clients read another copy
  - Background rebalance
- Task fails - Try again
  - Retries possible because of *idempotence*
- Namenode crash?
  - uh-oh

# Triple-Store Operations

- Load data (i.e. select data)
- Persist data (i.e. save to disk)
- Reload triple-store (i.e. restart)
- Run inferencing
- Respond to queries

# Query Overview



Graph Data

Map: Assign variables for 1st clause
Reduce: Remove duplicates

Map:
1. Assign variables for next clause
2. Map past partial assignments, Key on common variable

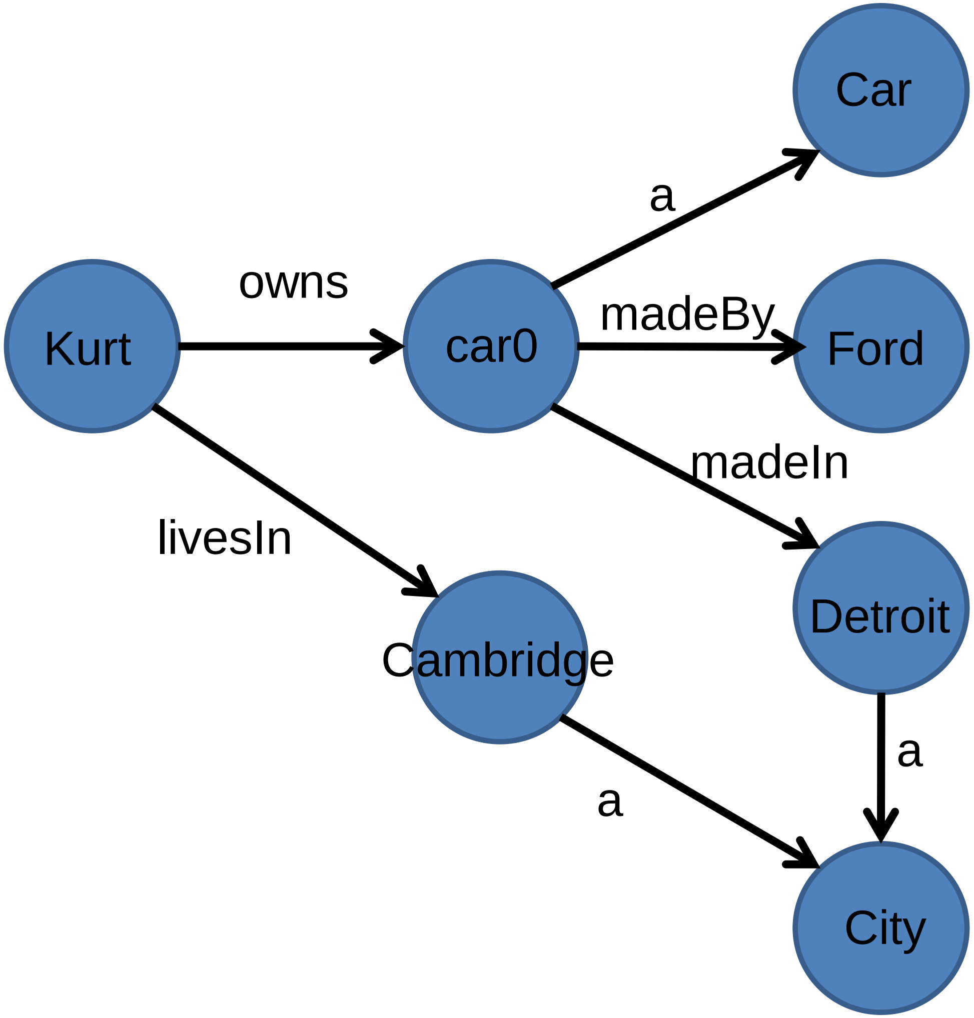
Reduce:
1. Join partial assignments on common variable
2. Remove duplicates

Map: Filter on SELECT variables
Reduce: Remove duplicates

Iterate over clauses

```
SELECT ?person
WHERE  {
   ?person :owns ?car .
   ?car a :Car .
   ?car :madeIn :Detroit
 }
```

# Graph Data


Car
a
owns
madeBy
Kurt
car0
Ford
madeIn
livesIn
Detroit
Cambridge
a
a
City

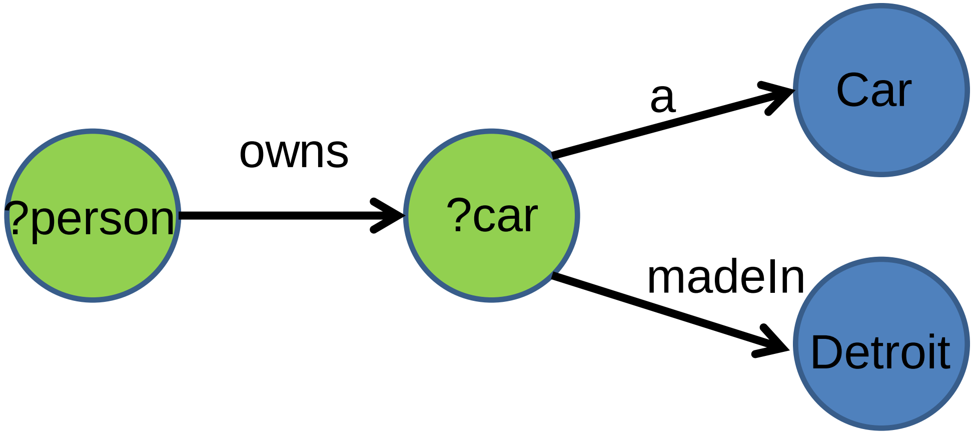
# Query Processing

- Initially using BBN-developed query processor
  - Starting interface with Jena
  - Sesame looks feasible.
- SHARD supports “most” of SPARQL.
  - Many unimplemented portions could be handled by query translator.
  - Large performance improvements possible with improved query processing.

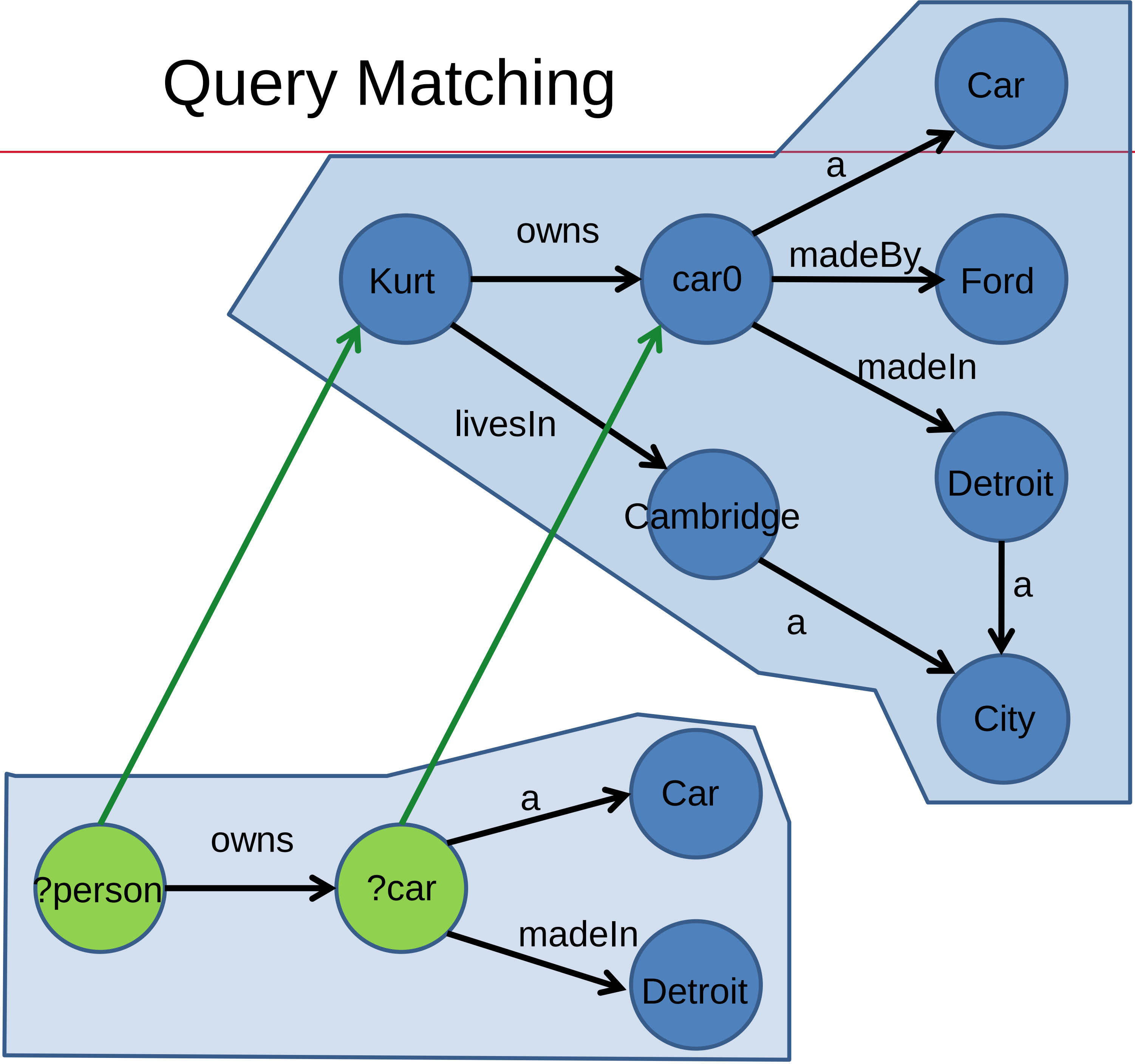
# SPARQL Query

All people who own a car made in Detroit:

```
SELECT ?person
WHERE  {
   ?person :owns ?car .
   ?car a :Car .
   ?car :madeIn :Detroit .
  }
```

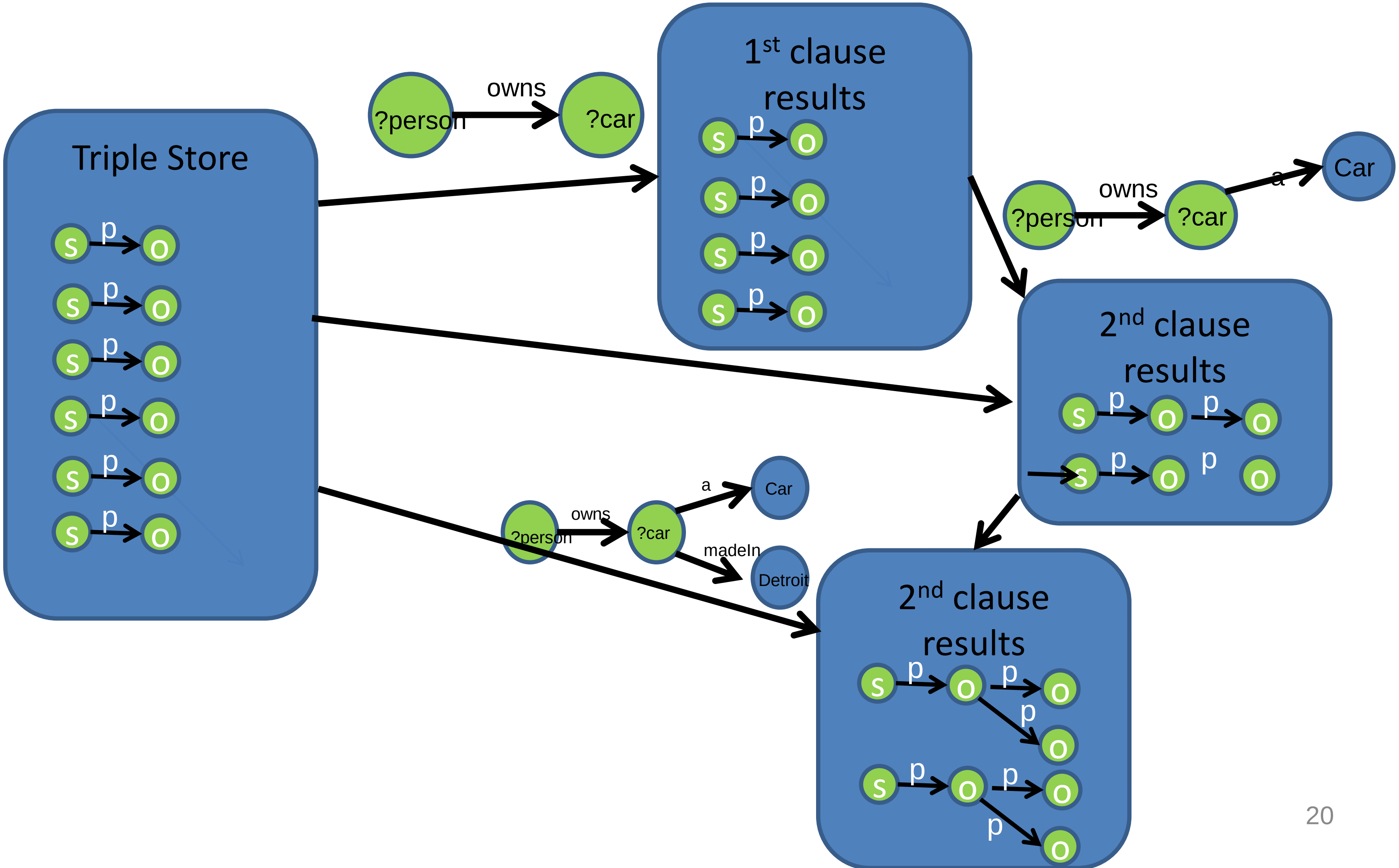


# Query Matching



# MR Triple Store

Triple Store is simple list of triples in HDFS



# Test Data

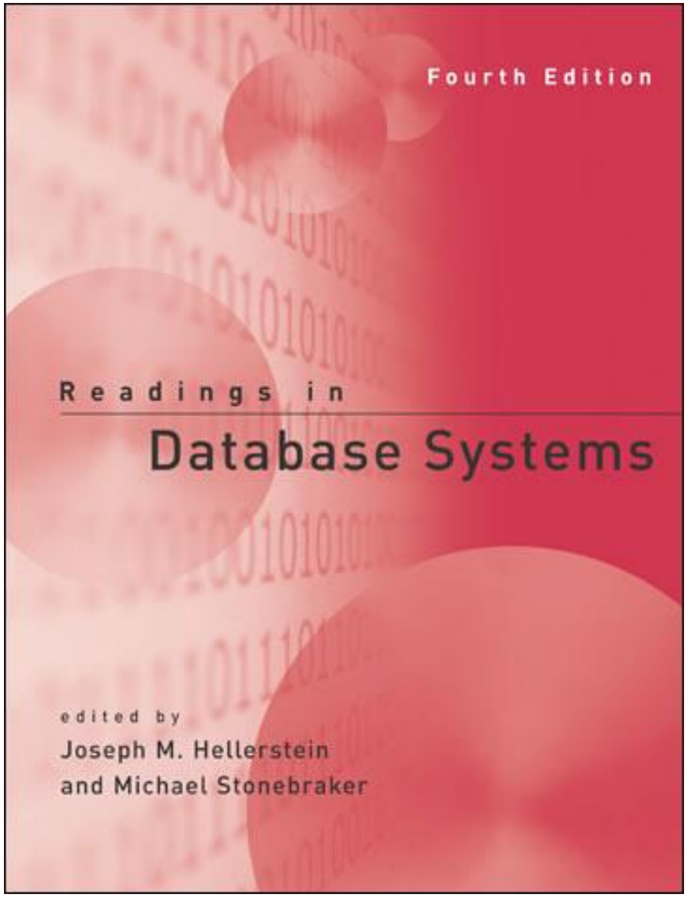
- Standard LUBM benchmark data
  - Artificial data on students, professors, courses, etc… at universities
- Deployed code on Amazon EC2 cloud
  - 19 XL nodes
- 6000 university dataset
  - Approximately 800 million edges in graph
- In general, performed comparably to “industrial” monolithic triple-stores

- Proof o’ Concept: For 6000 universities (approx. 800 million triples):
  Query 1: 404 sec. (approx 0.1 hr.)
  Query 9: 740 sec. (approx 0.2 hr.)
  Query 14: 118 sec. (approx 0.03 hr.)
- Sesame+DAMLDB:
  - Query 1: approx 0.1hr,
  - Query 9: approx 1 hr
  - Query 14: approx. 1 hr
- Jena+DAMLDB for 550 million triples:
  - Query 1: approx 0.001 hr,
  - Query 9: approx 1 hr
  - Query 14: approx. 5 hr

# Deficiencies?
# Ongoing Research?

# Optimizations

- For a single query....
  For a single workflow...
  Across workflows...
- Bring out last century’s DB research! (joins)
  And file system research too! (RAID)
- HadoopDB (Yale)
- Data Formats (yes, in ’10)



Fourth Edition

Readings in
Database Systems

edited by
Joseph M. Hellerstein
and Michael Stonebraker

# Release plans

- Tentative Open-Source release
  - BSD license planned

# Thanks!
# Questions?

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