Signal Processing on Databases

Jeremy Kepner

Lecture 3: Entity Analysis in Unstructured Data

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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Outline

- **Introduction**
  - **Webolution**
  - **As is, is OK**
  - **D4M**
- **Technologies**
- **Results**
- **Demo**
- **Summary**

Primordial Web

Kepner & Beaudry 1992, Visual Intelligence Corp (now GE Intelligent Platforms)

Browser (html):

http put

http get

Server (http):

Gopher

Language:

perl

SQL

data

Database (sql):

SYBASE

Client

Server

Database

- Browser GUI? HTTP for files? Perl for analysis? SQL for data?
- A lot of work just to view data.
- Won't catch on.

Cambrian Web

Browser (html):

http put

http get

Server (http):

Apache Windows Server

Language:

Java php perl python Ruby

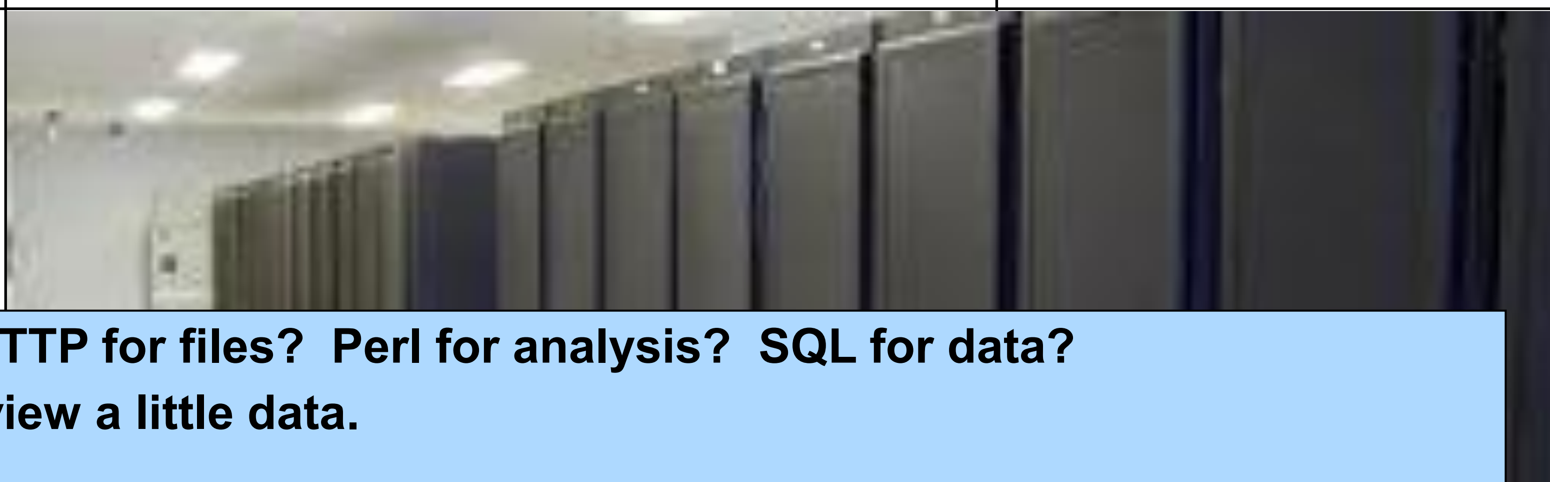
SQL

data

Database (sql):

SYBASE ORACLE IBM DB2 Microsoft SQL Server MySQL

Client | **Server** | **Database**



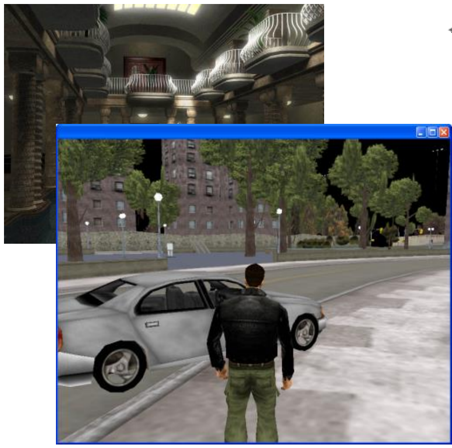
- Browser GUI? HTTP for files? Perl for analysis? SQL for data?
- A lot of work to view a little data.
- ~~Won't catch on.~~

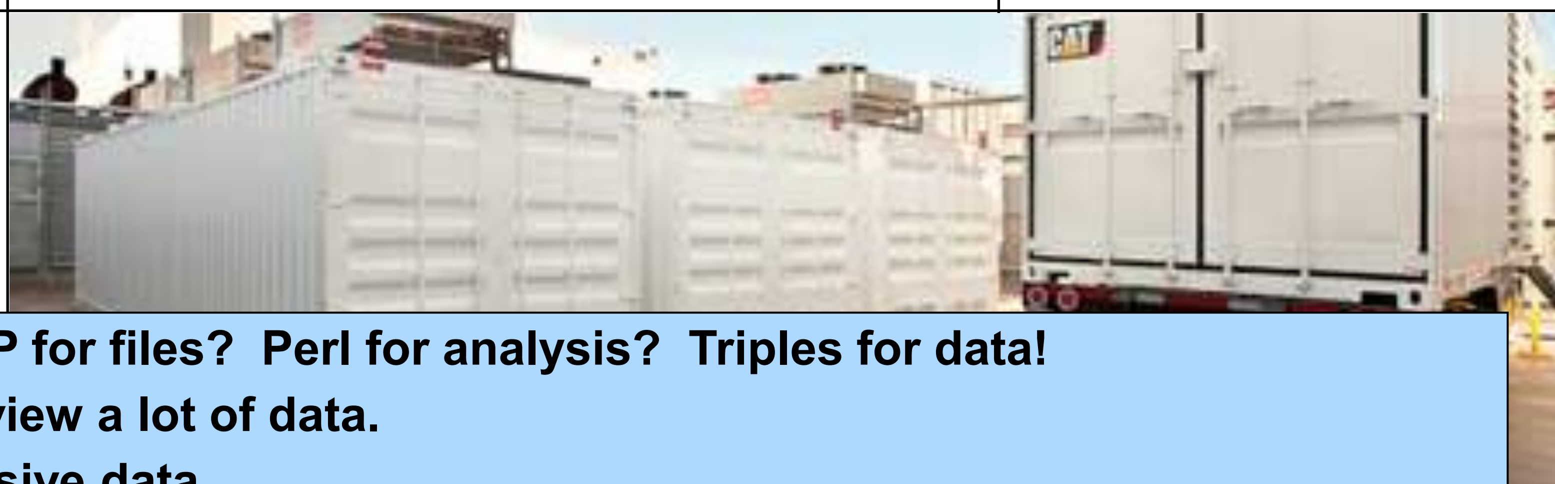
Modern Web

Client	Server	Database
Game (data):	**Server (http):** Apache, Windows Server **Language:** Java, php, perl, python, Ruby	**Database (triples):** BigTable, riak, Cassandra, HBASE

http put →
← http get

java →
← data

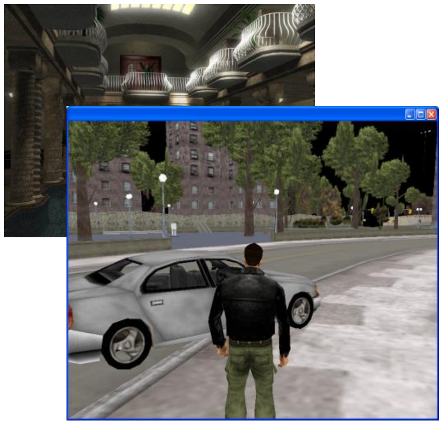




- Game GUI! HTTP for files? Perl for analysis? Triples for data!
- A lot of work to view a lot of data.
- Great view. Massive data.

Modern Web

Game (data):



http put

http get

Server (http):

Apache Windows Server

Language:

Java php perl python Ruby

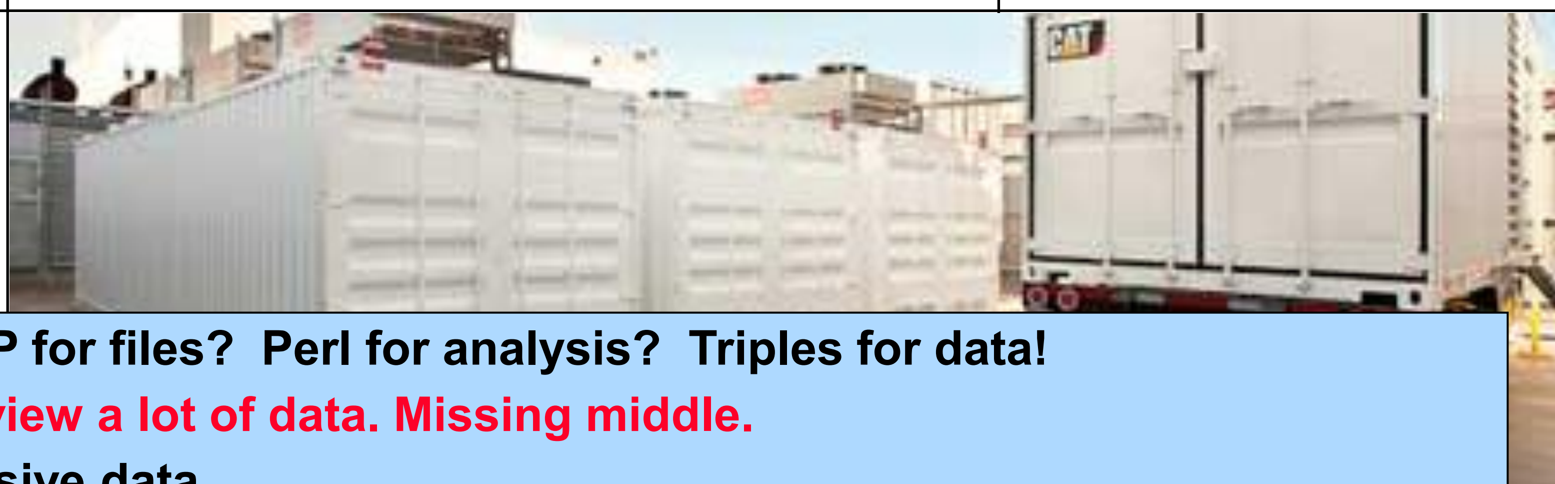
java

data

Database (triples):

BigTable riak Cassandra HBASE

Client	Server	Database

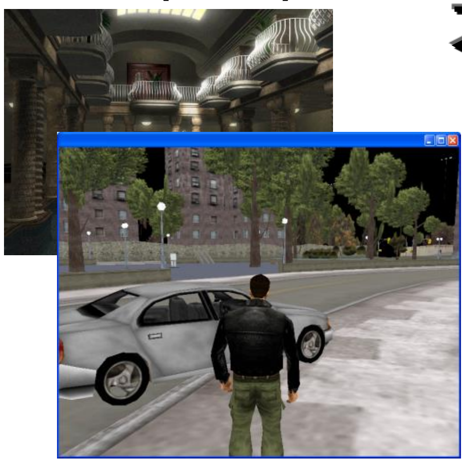


- Game GUI! HTTP for files? Perl for analysis? Triples for data!
- A lot of work to view a lot of data. Missing middle.
- Great view. Massive data.

Future Web?

Game (data):	Server (files):	Database (triples):
	graphs ⇄ graphs portal	graphs ⇄ graphs portal

Game (data):



graphs
graphs
portal

Server (files):

lustre

Language:

D4M

graphs
graphs
portal

Database (triples):

BigTable

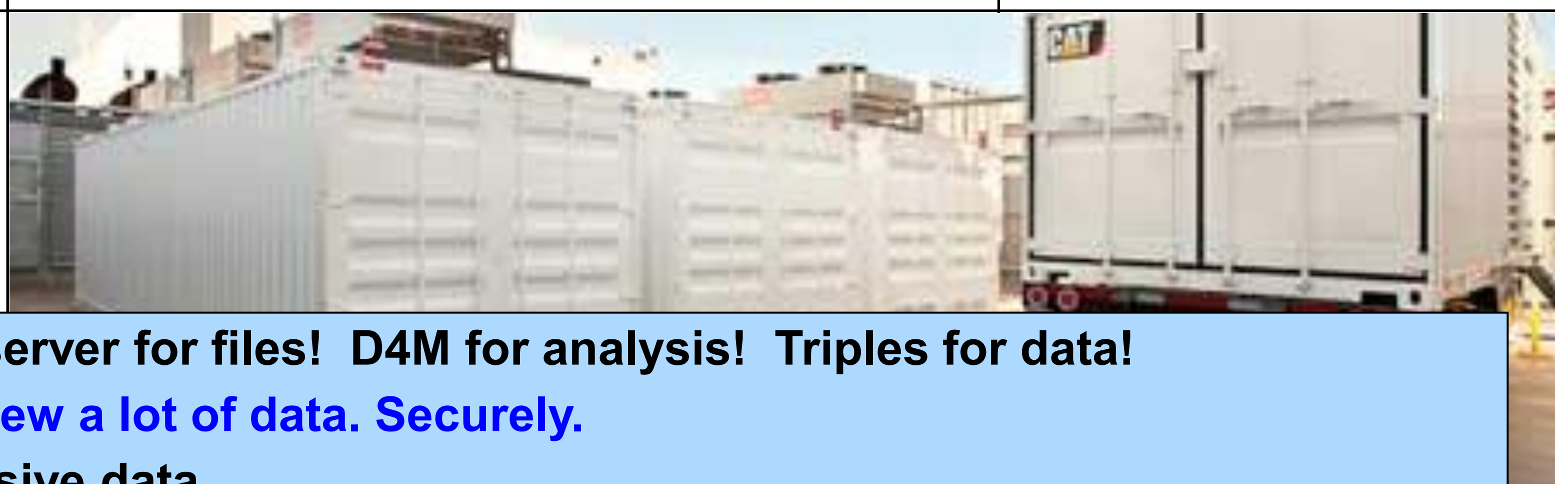
riak

Cassandra

HBASE

Client

Server

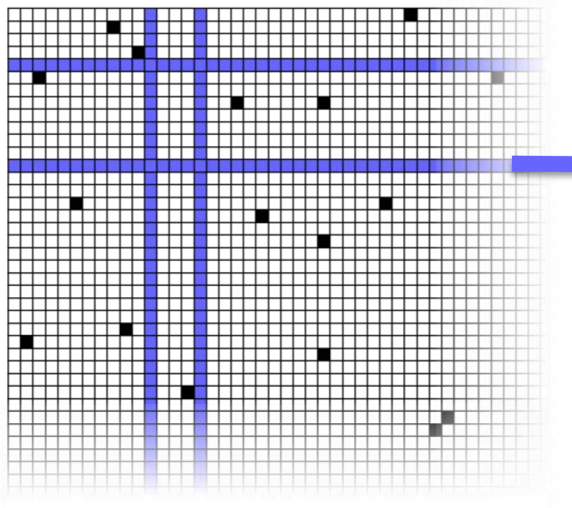


Database

- Game GUI! Fileserver for files! D4M for analysis! Triples for data!
- A little work to view a lot of data. Securely.
- Great view. Massive data.

D4M: "Databases for Matlab"

Triple Store
Distributed Database

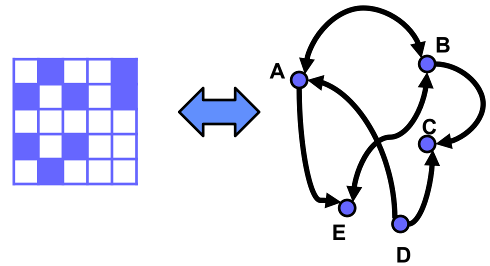


Triple store are high performance distributed databases for heterogeneous data

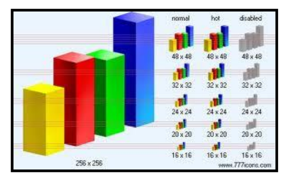
D4M
Dynamic
Distributed
Dimensional
Data
Model

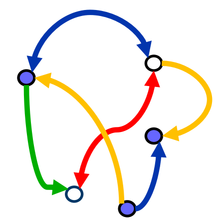
Query:
Alice
Bob
Cathy
David
Earl

Associative Arrays
Numerical Computing Environment



A D4M query returns a sparse matrix or graph from Cloudbase…





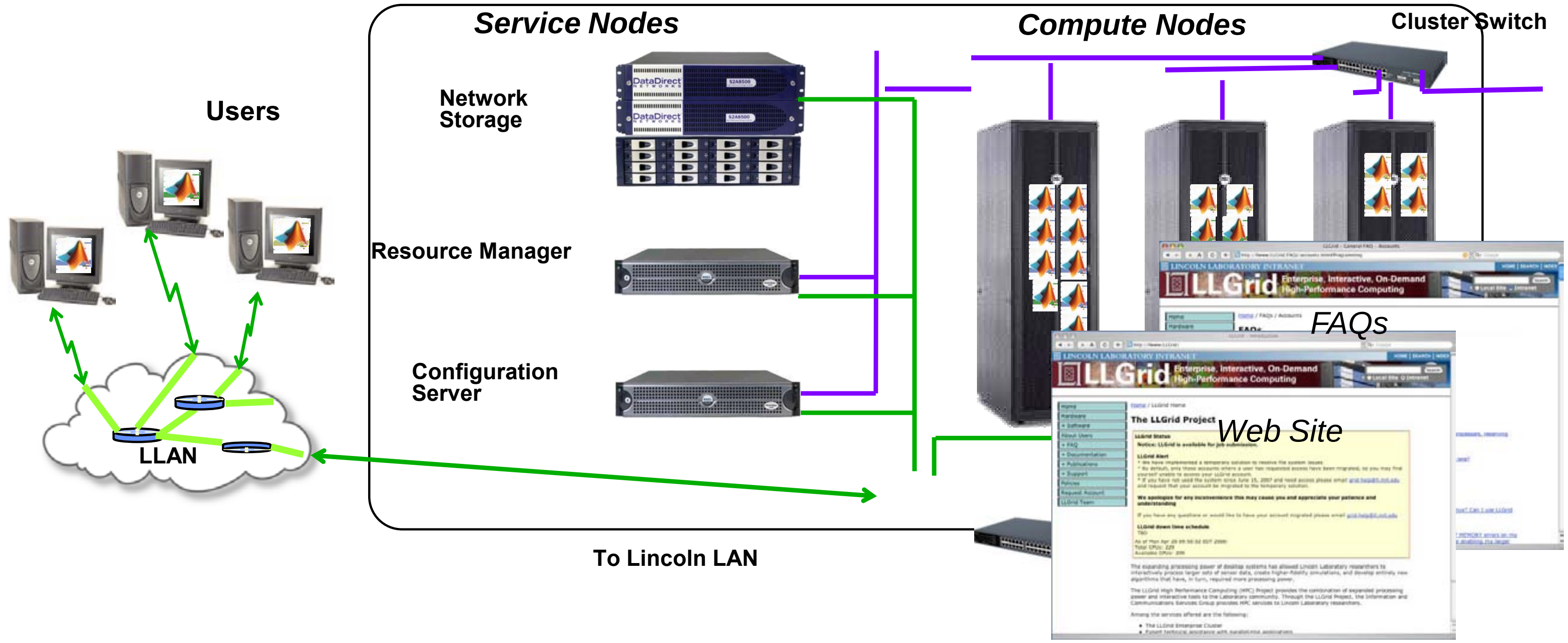
…for statistical signal processing or graph analysis in MATLAB

- **D4M binds Associative Arrays to Triple Store, enabling rapid prototyping of data-intensive cloud analytics and visualization**

Outline

- Introduction
- Technologies
  - Hardware
  - Cloud software
  - Associative Arrays
- Results
- Demo
- Summary

What is LL Grid?



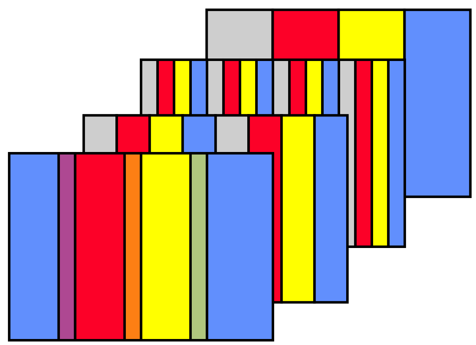
- LLGrid is a ~500 user ~2000 processor system
- World's only desktop interactive supercomputer
  - Dramatically easier to use than any other supercomputer
  - Highest fraction of staff using (20%) supercomputing of any organization on the planet
- Foundation of Supercomputing in Massachusetts

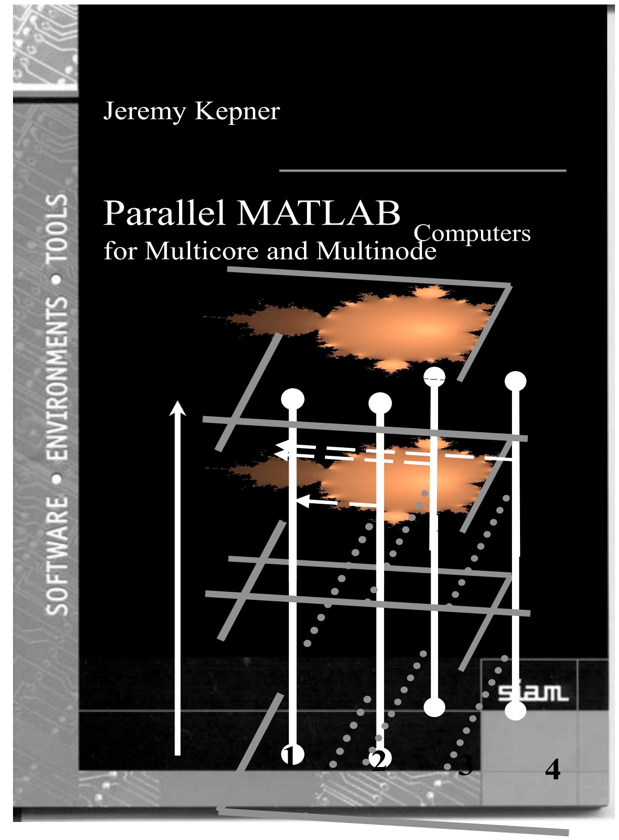
Why is LLGrid easier to use?

Universal Parallel Matlab programming →

```
Amap = map([Np 1],{},0:Np-1);
Bmap = map([1 Np],{},0:Np-1);
A = rand(M,N,Amap);
B = zeros(M,N,Bmap);
B(:,:) = fft(A);
```

- **pMatlab runs in all parallel Matlab environments**
- **Only a few functions are needed**
  - **Np**
  - **Pid**
  - **map**
  - **local**
  - **put_local**
  - **global_index**
  - **agg**
  - **SendMsg/RecvMsg**





- **Distributed arrays have been recognized as the easiest way to program a parallel computers since the 1970s**
  - **Only a small number of distributed array functions are necessary to write nearly all parallel programs**
- **LLGrid is the first system to deploy interactive distributed arrays**

Cloud Computing Concepts

Data Intensive Computing

- Compute architecture for large scale data analysis
  - Billions of records/day, trillions of stored records, petabytes of storage
    - Google File System 2003
    - Google MapReduce 2004
    - Google BigTable 2006
- Design Parameters
  - Performance and scale
  - Optimized for ingest, query and analysis
  - Co-mingled data
  - Relaxed data model
  - Simplified programming
- Community:

Utility Computing

- Compute services for outsourcing IT
  - Concurrent, independent users operating across millions of records and terabytes of data
    - IT as a Service
    - Infrastructure as a Service (IaaS)
    - Platform as a Service (PaaS)
    - Software as a Service (SaaS)
- Design Parameters
  - Isolation of user data and computation
  - Portability of data with applications
  - Hosting traditional applications
  - Lower cost of ownership
  - Capacity on demand
- Community:

The Big Four Cloud Ecosystems

Enterprise

IaaS
- Interactive
- On-demand
- Elastic

Supercomputing

PaaS
- High performance
- Parallel Languages
- Scientific computing

PaaS
- Java
- Map/Reduce
- Easy admin

Big Data

SaaS
- Indexing
- Search
- Security

DBMS

- **Each ecosystem is at the center of a multi-$B market**
- **Pros/cons of each are numerous; diverging hardware/software**
- **Some missions can exist wholly in one ecosystem; some can't**

IaaS: Infrastructure as Service
PaaS: Platform as a Service
SaaS: Software as a Service

The Big Four Cloud Ecosystems

Enterprise

LLGrid

Supercomputing

<u>IaaS</u>
- Interactive
- On-demand
- Elastic

<u>PaaS</u>
- High performance
- Parallel Languages
- Scientific computing

<u>PaaS</u>
- Java
- Map/Reduce
- Easy admin

Big Data

accumulo

HBASE

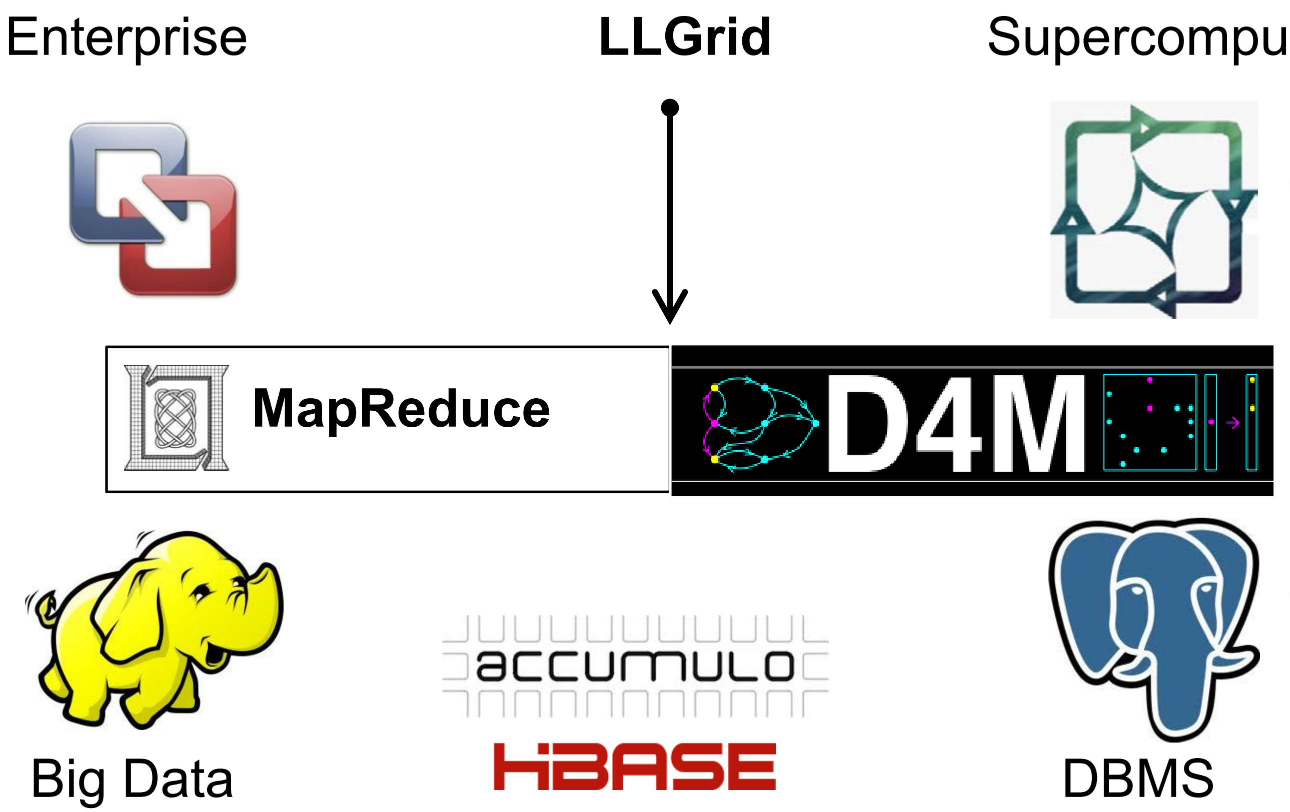
DBMS

<u>SaaS</u>
- Indexing
- Search
- Security

- **LLGrid provides interactive, on-demand supercomputing**
- **Accumulo database provides high performance indexing, search, and authorizations within a Hadoop environment**

IaaS: Infrastructure as Service
PaaS: Platform as a Service
SaaS: Software as a Service

The Big Four Cloud Ecosystems



IaaS
- Interactive
- On-demand
- Elastic

PaaS
- High performance
- Parallel Languages
- Scientific computing

PaaS
- Java
- Map/Reduce
- Easy admin

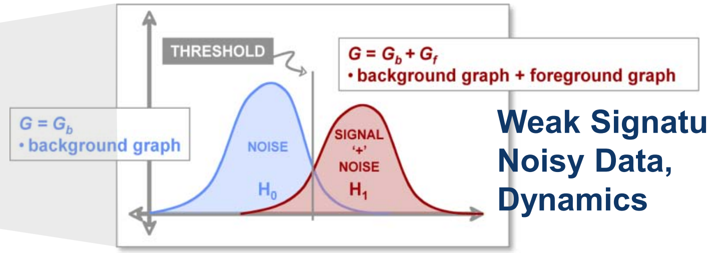
SaaS
- Indexing
- Search
- Security

- **LLGrid MapReduce provides map/reduce interface to supercomputing**
- **D4M provides an interactive parallel scientific computing environment to databases**

IaaS: Infrastructure as Service
PaaS: Platform as a Service
SaaS: Software as a Service

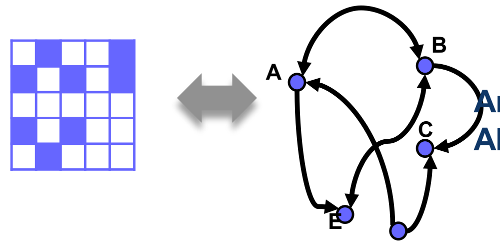
Big Compute + Big Data Stack

Novel Analytics for: Text, Cyber, Bio



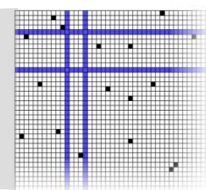
Weak Signatures, Noisy Data, Dynamics

High Level Composable API: D4M ("Databases for Matlab")



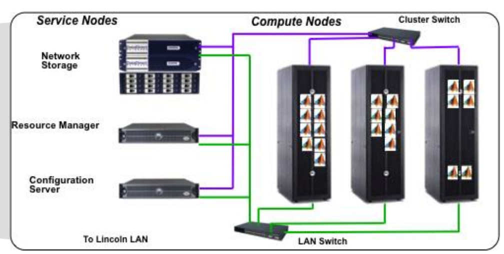
Array Algebra

Distributed Database: Accumulo/HBase (triple store)



Distributed Database/ Distributed File System

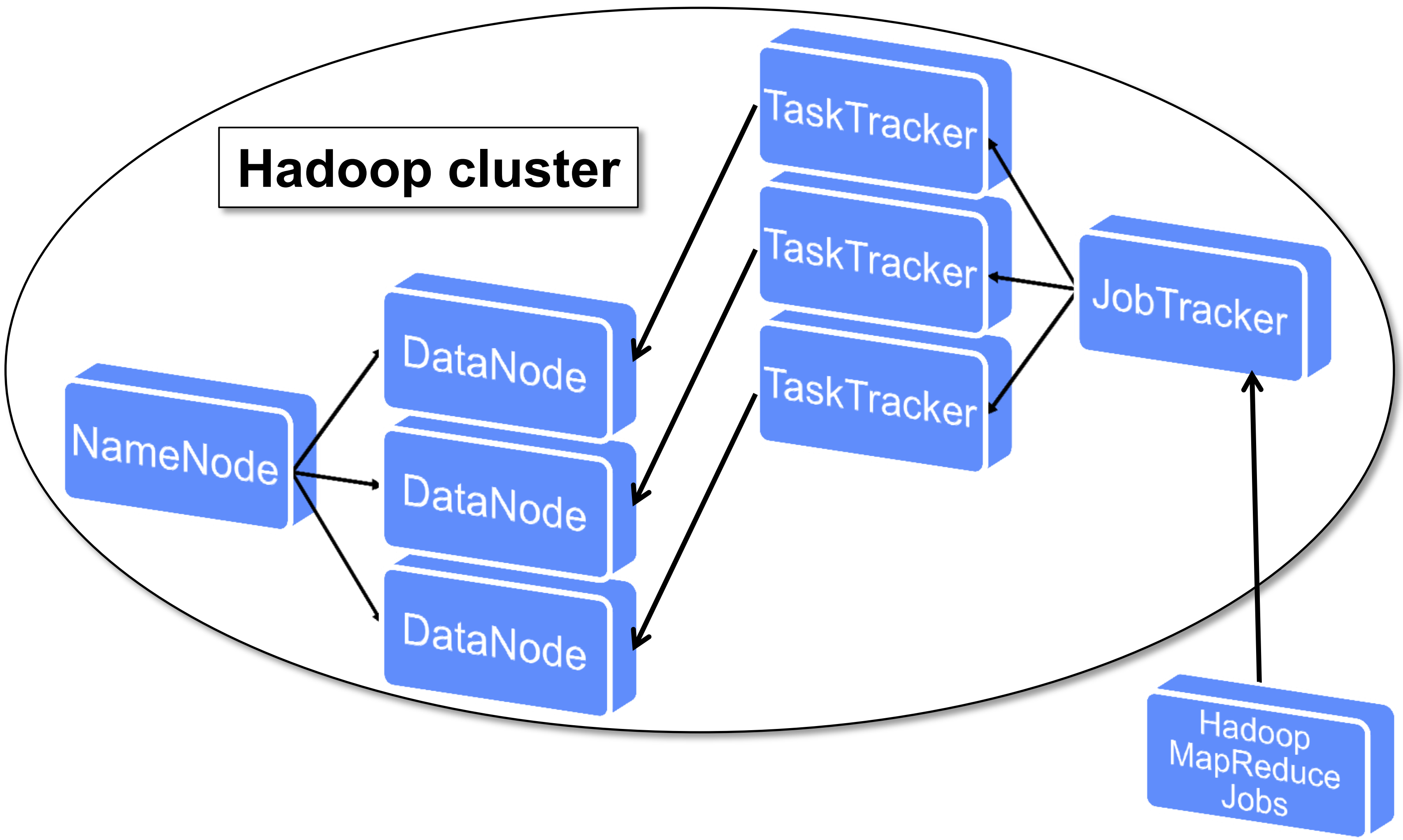
High Performance Computing: LLGrid + Hadoop



Interactive Super-computing

- **Combining Big Compute and Big Data enables entirely new domains**

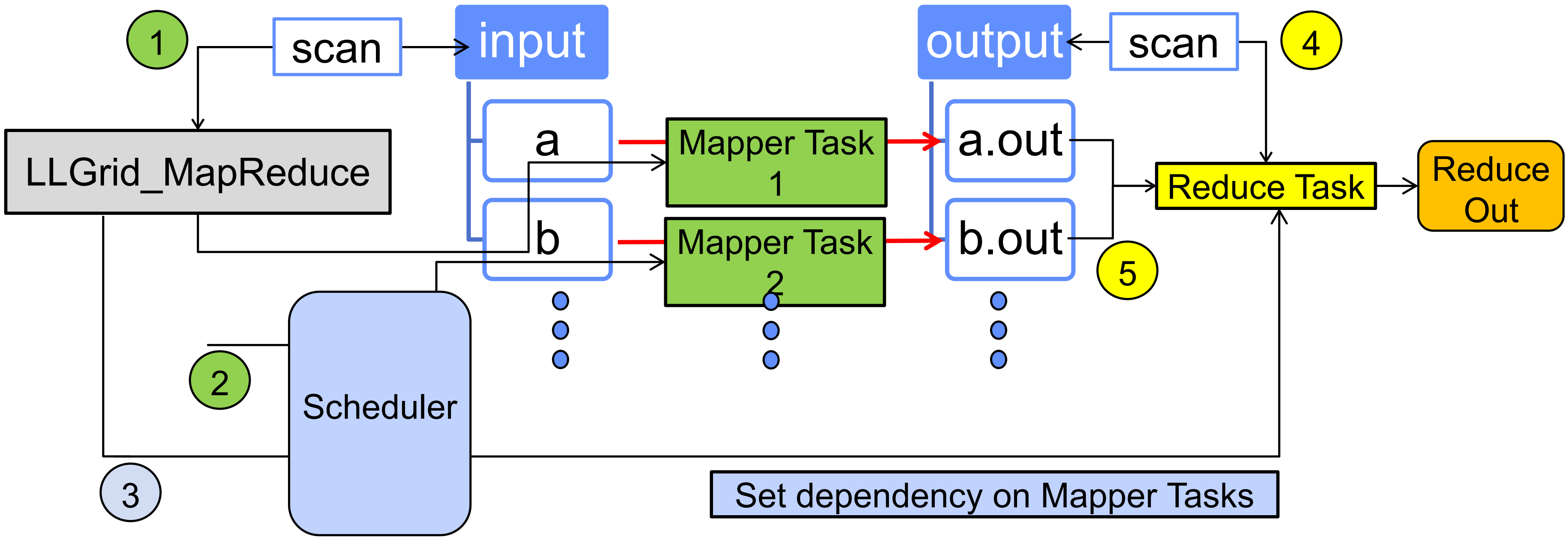
Hadoop Architecture Overview



Hadoop: Strengths and Weaknesses

- What works well
  - Distributed processing of large data
    - Indexing log files
    - Sorting data
  - Scale up from single servers to thousands of machines
    - Local computation and storage
  - Detect and handle failures at the application layer
    - Highly-available service on top of a cluster of computers
- Some difficulties are
  - Controlling compute resources for a given job
    - Full blown, greedy scheduling
  - Multi-user environments
    - Not easy to provide fair-share control on their use of Hadoop cluster
  - Non-Java programmers
    - Takes time to learn the parallel programming API for Java

LLGrid_MapReduce Architecture



- **LLGrid MapReduce provides a language agnostic and scheduler agnostic map/reduce interface in a supercomputing environment**

Outline

- Introduction
- Technologies
  - Hardware
  - Cloud software
  - D4M
- Results
- Demo
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Multi-Dimensional Associative Arrays

- **Extends associative arrays to 2D and mixed data types**

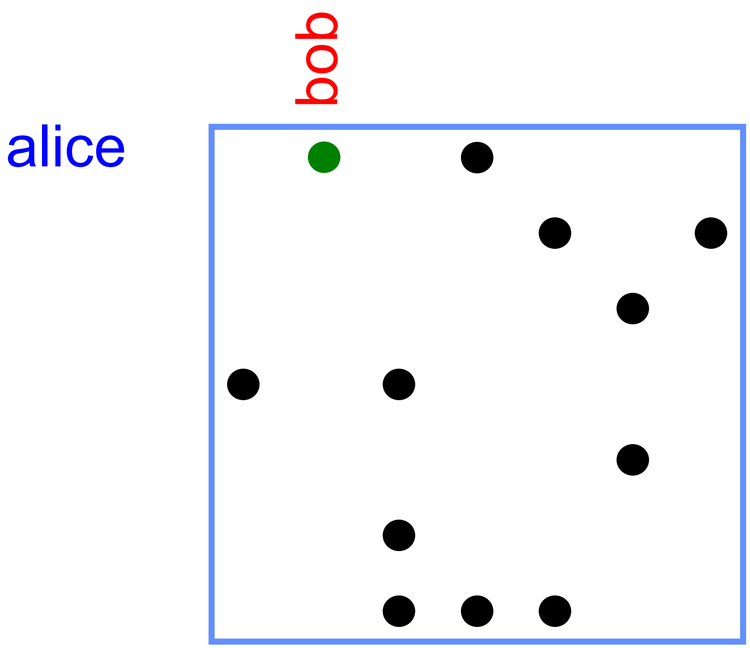
  A('alice ','bob ') = 'cited '

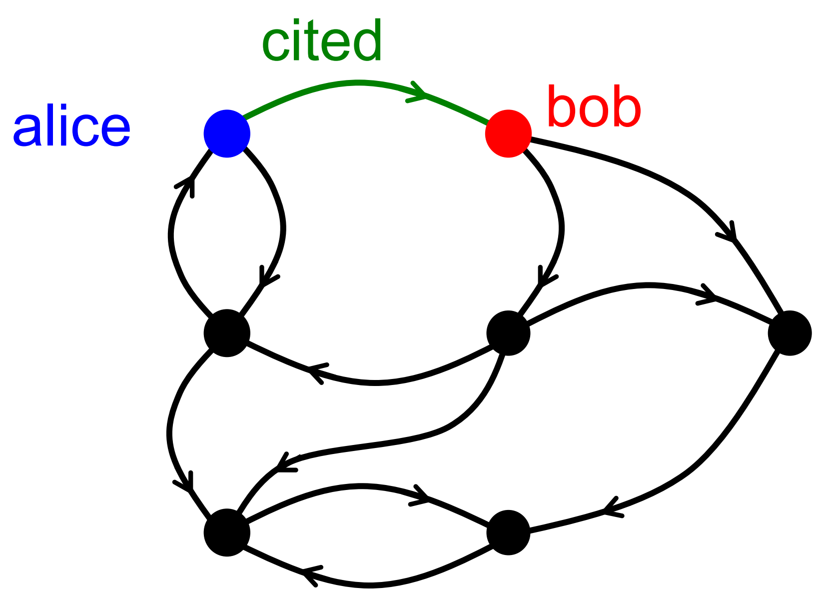
  or A('alice ','bob ') = 47.0

- **Key innovation: 2D is 1-to-1 with triple store**

  ('alice ','bob ','cited ')

  or ('alice ','bob ',47.0)





Composable Associative Arrays

- **Key innovation: mathematical closure**
  - **all associative array operations return associative arrays**

- **Enables composable mathematical operations**

A + B   A - B   A & B   A|B   A*B

- **Enables composable query operations via array indexing**

A('alice bob ',:)   A('alice ',:)   A('al* ',:)

A('alice : bob ',:)   A(1:2,:)   A == 47.0

- **Simple to implement in a library (~2000 lines) in programming environments with: 1st class support of 2D arrays, operator overloading, sparse linear algebra**

- **Complex queries with ~50x less effort than Java/SQL**
- **Naturally leads to high performance parallel implementation**

Universal "Exploded" Schema

Input Data

Time	src_ip	domain	dest_ip
2001-01-01	a		a
2001-01-02	b	b	
2001-01-03		c	c

Triple Store Table: Ttranspose

	2001-01-01	2001-01-02	2001-01-03
src_ip/a	1		
src_ip/b		1	
domain/b		1	
domain/c			1
dest_ip/a	1		
dest_ip/c			1

	src_ip/a	src_ip/b	domain/b	domain/c	dest_ip/a	dest_ip/c
2001-01-01	1				1	
2001-01-02		1	1			
2001-01-03				1		1

Triple Store Table: T

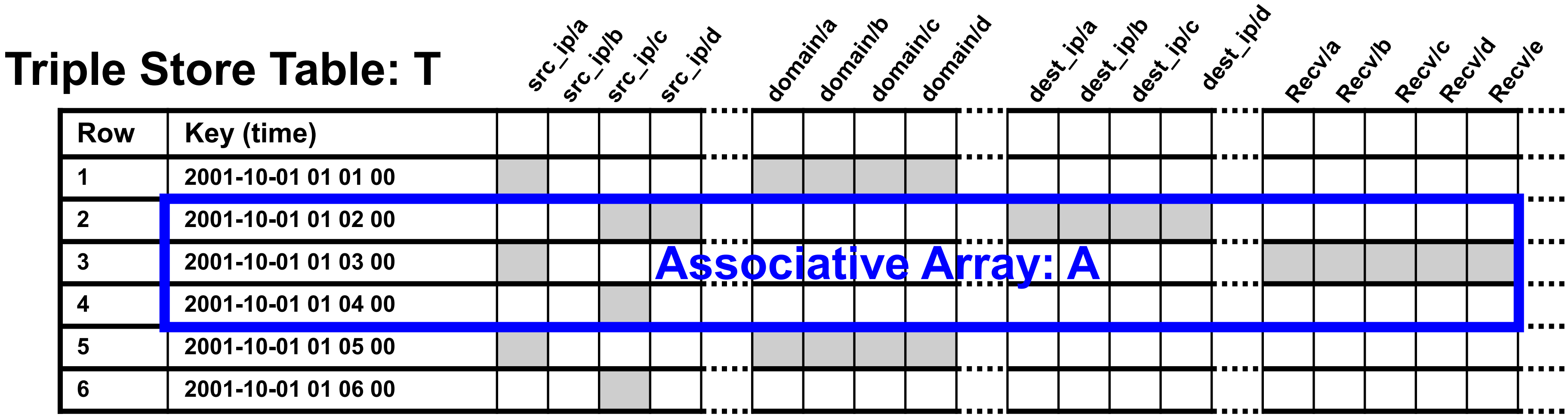
Key Innovations

- Handles all data into a *single* table representation
- Transpose pairs allows quick look up of *either* row or column

Outline

- Introduction
- Technologies
- Results
  - Benchmark performance
  - Facet search
  - Management and monitoring
- Demo
- Summary

Stats Diagram



- Copy a set of rows from T into associative array **A**
- Perform the following statistical calculations on **A**
  - Column count: how many times each column appears in **A**
  - Column type count: how many times each column type appears in **A**
  - Column covariance: how many times a each pair of columns in **A** appear in the same row together
  - Column covariance: how many times a each pair of column types in **A** appear in the same row together

- Good for identifying column types, gaps, clutter, and correlations

Stats Diagram

Triple Store Table: T

Row	Key (time)	src_ip/a	src_ip/b	src_ip/c	src_ip/d	domain/a	domain/b	domain/c	domain/d	dest_ip/a	dest_ip/b	dest_ip/c	dest_ip/d	Recv/a	Recv/b	Recv/c	Recv/d	Recv/e
1	2001-10-01 01 01 00																	
2	2001-10-01 01 02 00																	
3	2001-10-01 01 03 00																	
4	2001-10-01 01 04 00																	
5	2001-10-01 01 05 00																	
6	2001-10-01 01 06 00																	

Associative Array: A

- **Copy a set of rows from T into associative array A**
- **Perform the following statistical calculations on A**
  - **Column count: how many times each column appears in A**
  - **Column type count: how many times each column type appears in A**
  - **Column covariance: how many times a each pair of columns in A appear in the same row together**
  - **Column covariance: how many times a each pair of column types in A appear in the same row together**

- **Good for identifying column types, gaps, clutter, and correlations**

Stats Implementation

- **Define a set of rows**

```
r = '2001-01-01 01 02 00,2001-01-01 01 03 00, 2001-01-01 01 04 00,'
```

- **Copy rows from table to associative array and convert** '1' **to** 1

```
A = double(logical(T(r,:)))
A = A(:,'src_ip/ *,domain/ *,dest_ip/ *,')
```

- **Find popular columns counts**

```
sum(A,1) > 200
```

- **Find popular pairs**

```
A' * A > 200
```

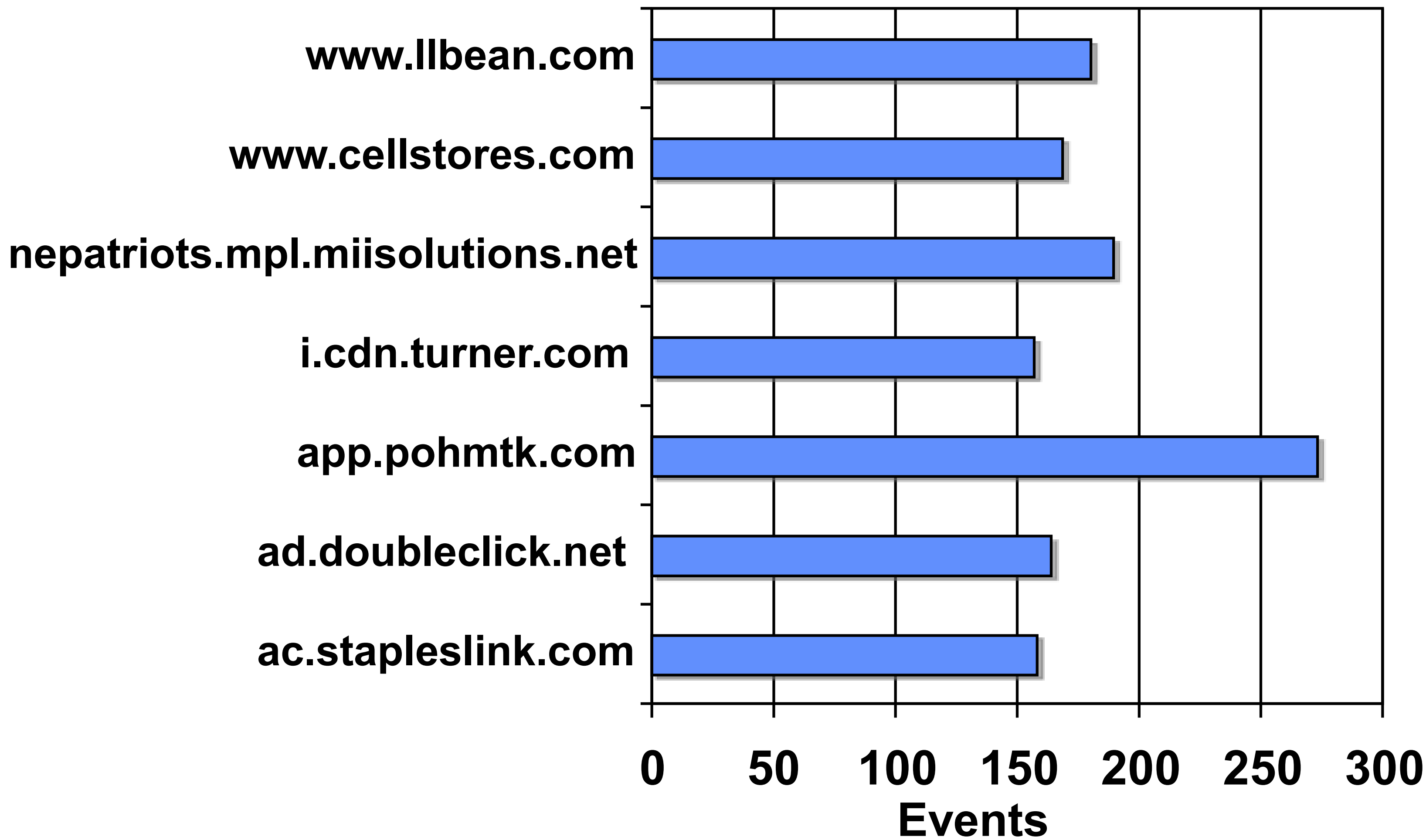
or

```
sqIn(A) > 200
```

- **Find domains with many dest IPs**

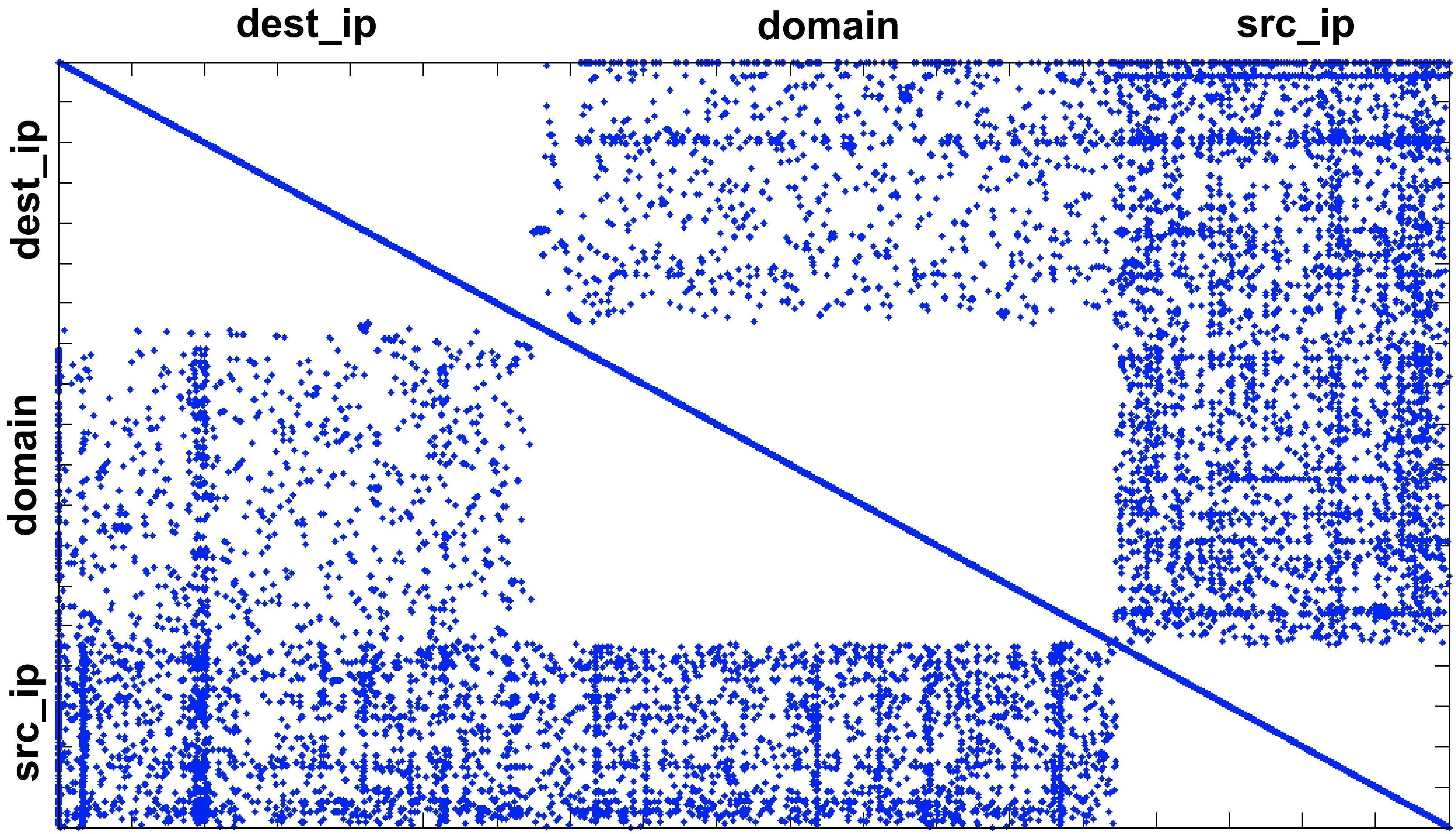
```
sum(double(logical(sqIn(A))),2) > 3
```

Count



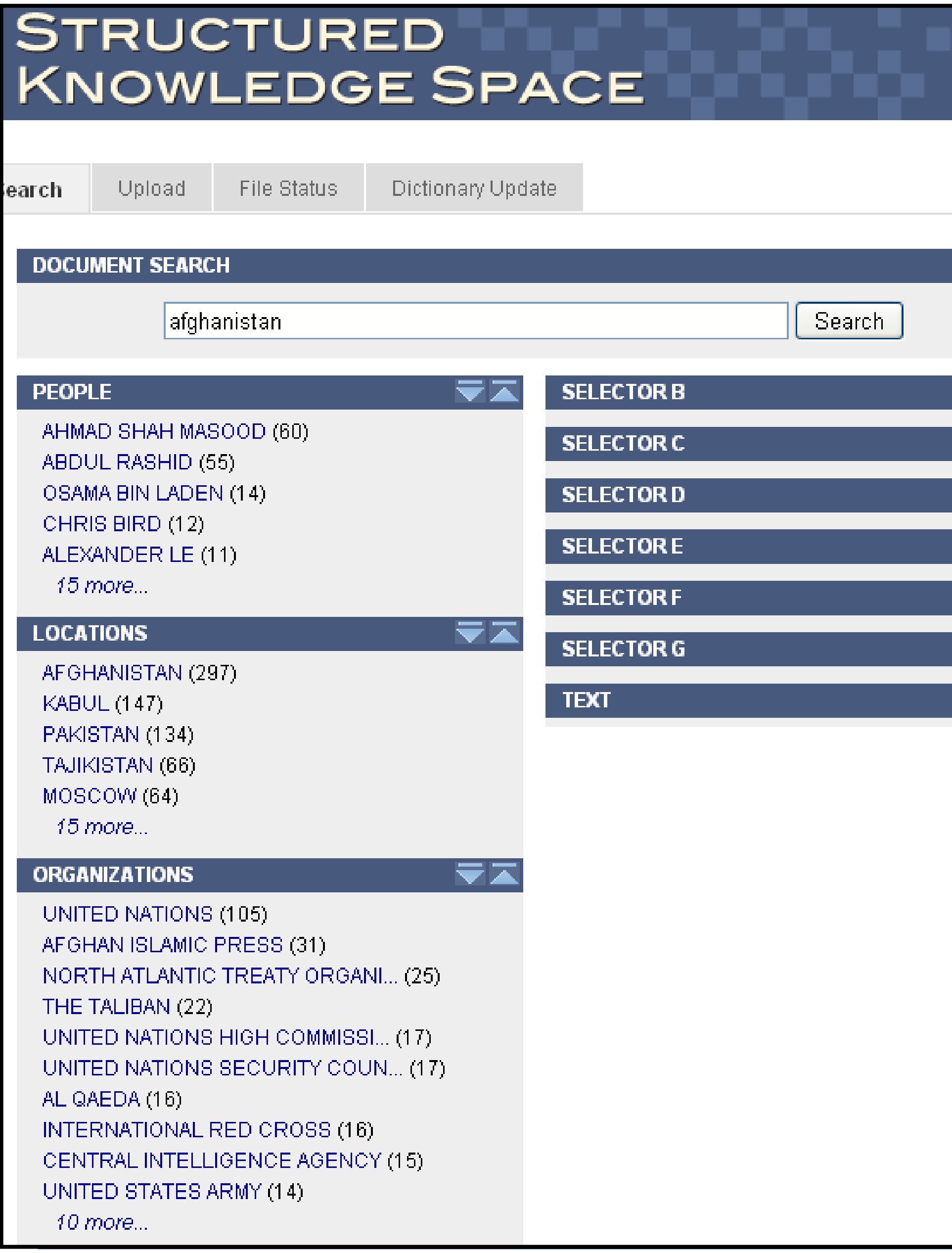
- Very easy to get elementary count info necessary for finding clutter and anomalies

Covariance



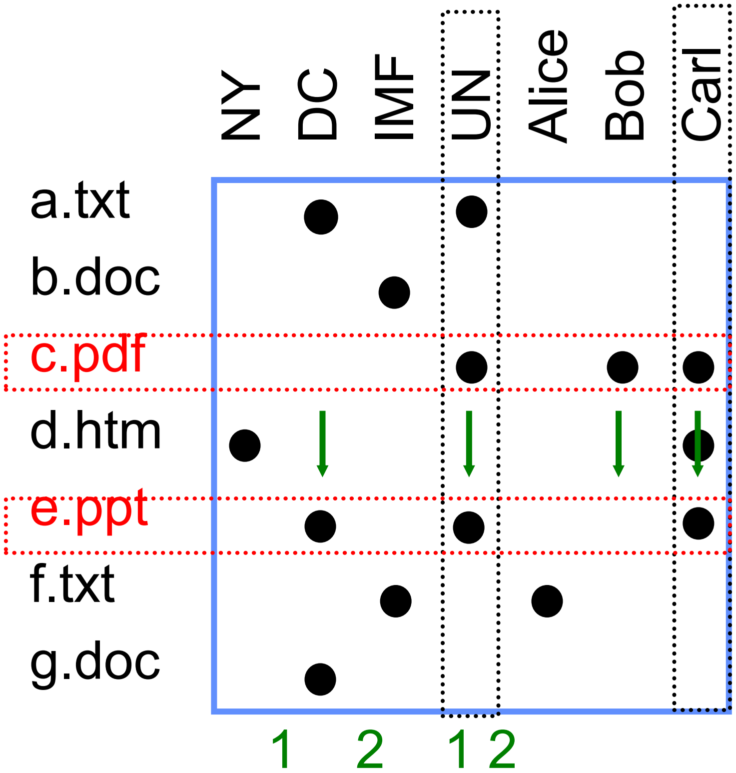
- **Adjacency matrix a natural result of covariance calculation**

Facet Search



- **Core analytic of SKS**
- **Give keyword distribution of a set of documents that share a common keyword(s)**
  - **Provides useful guide to what keyword to select next**
- **Currently implemented with several hundreds of lines of Java/SQL**
- **Associative array implementation has 1 line**

Facet Search Algorithm



- Associative array relates documents to place, org and person entities

$$A(x,y) : S^{NxM} \rightarrow R$$

- Facets y_1=UN, y_2=Carl
- Documents that contain both

$$\underline{A}(:,y_1) \,\&\, \underline{A}(:,y_2)$$

- Entity counts in the above set of documents obtained via matrix multiply

$$(\, \underline{A}(:,y_1) \,\&\, \underline{A}(:,y_2)\,)^t \; A$$

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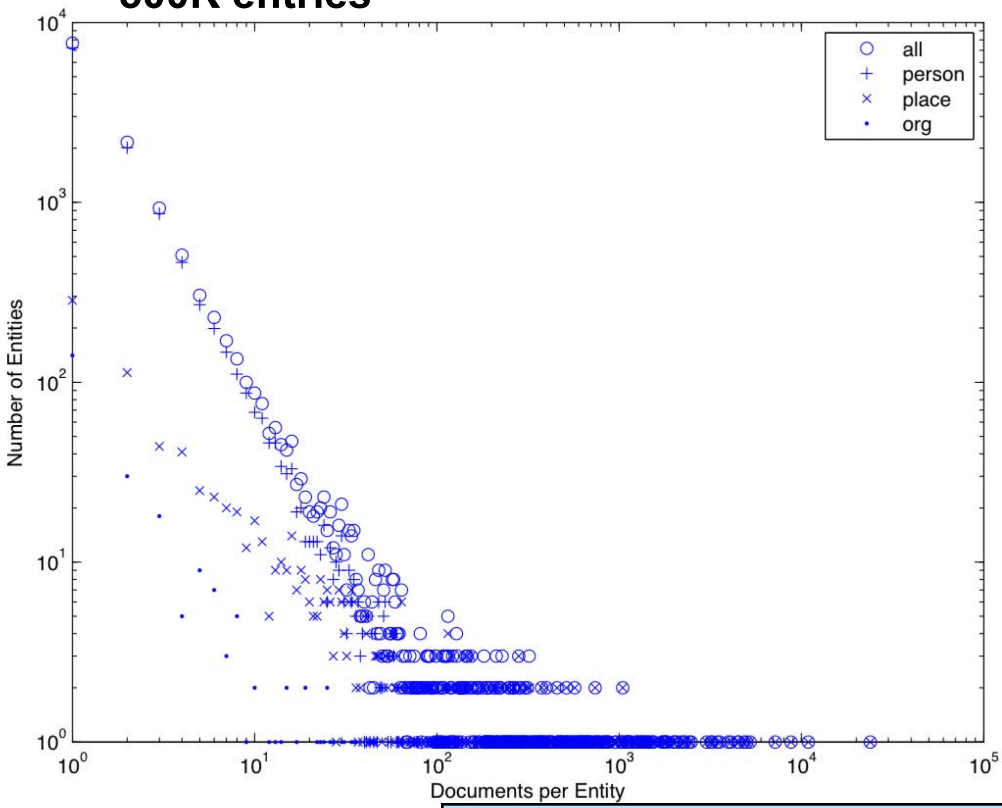
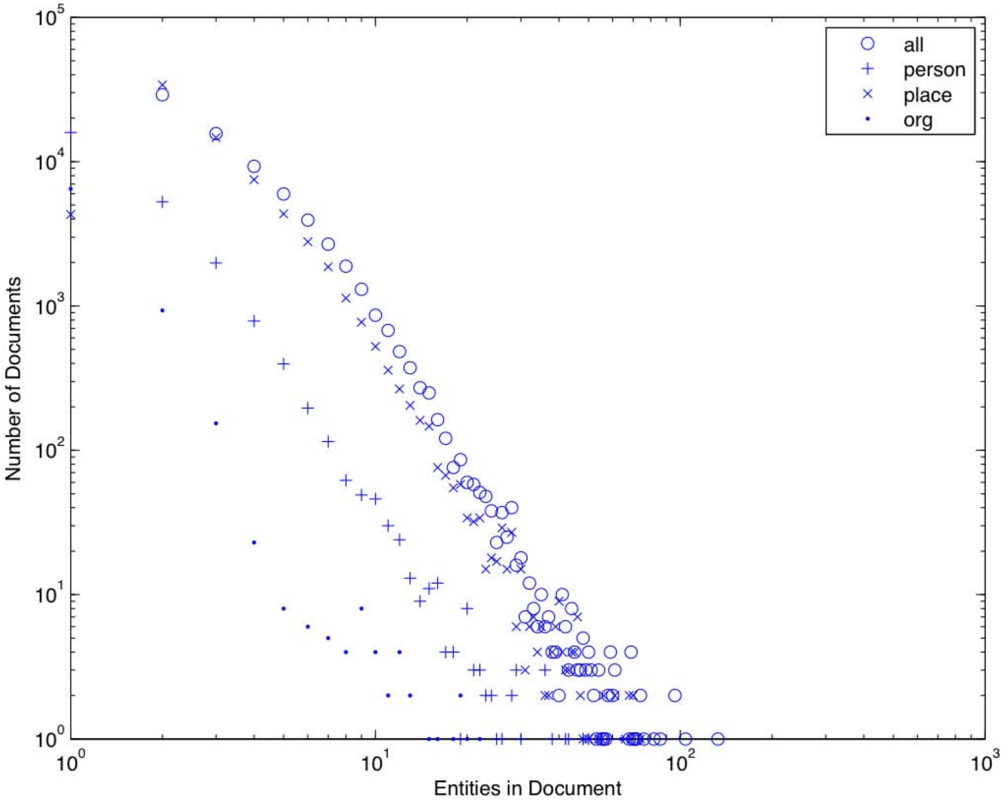
Reuters Corpus V1 (NIST)
1996-08-20 to 1997-08-19 (Released 2000-11-03

- **810,000 Reuters news blurbs**
- **Picked 70,000 and found 13,000 entities**
- **A is a 70Kx13K associative array with 500K entries**





- **Power laws everywhere**
- **Number of persons >> number of places**
- **Number of document/places>> number of document/person**

Terminal — ssh — 77×27

```
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>> %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
>> % Connecting to a database.
>> %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
>>
>>
```

Summary

- Web evolution has resulted in a new class of technologies for
  - Display (game interfaces)
  - Analysis (D4M)
  - Storage (triple stores)
- D4M is a novel technology that allows complex analytics to be implement with significantly less effort than traditional approaches
- D4M is built on composable associative arrays which admit linear algebraic manipulation

Example Code & Assignment

- Example Code (end of Lecture 3 and start of lecture 4)
  - d4m_api/examples/2Apps/1EntityAnalysis
  - d4m_api/examples/2Apps/2TrackAnalysis

- Assignment
  - None