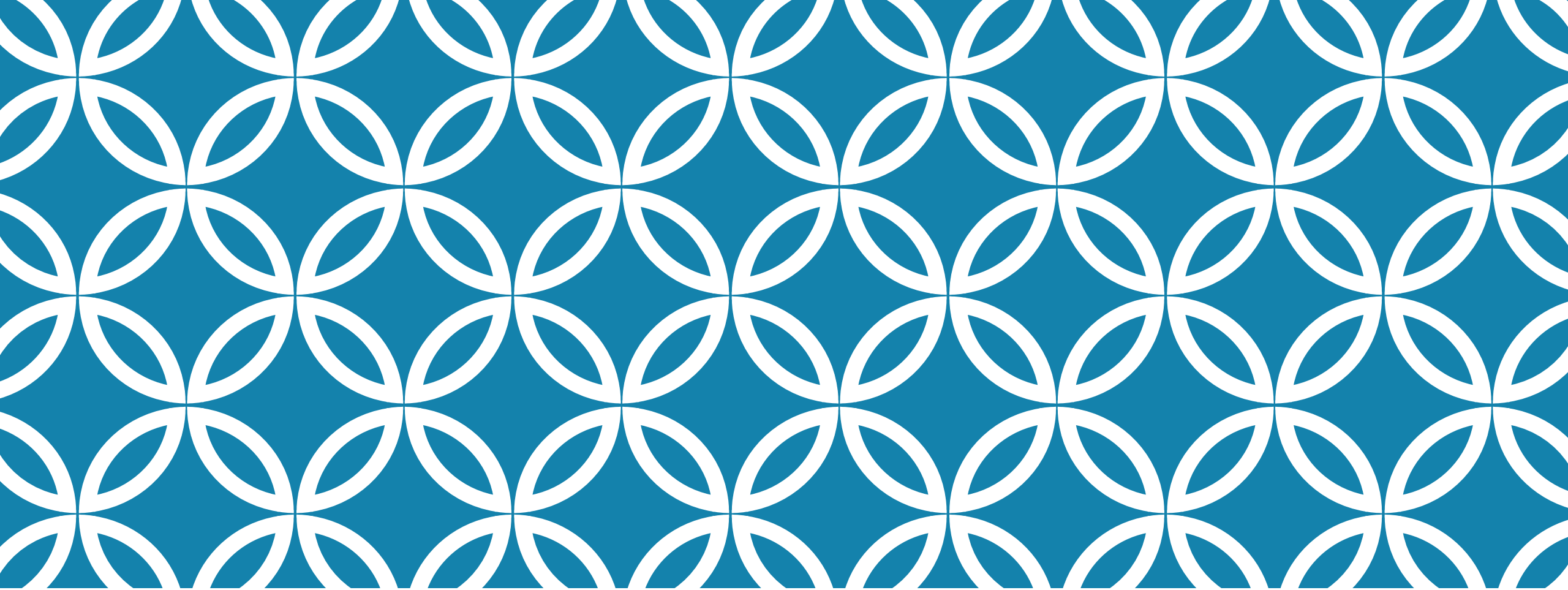

LECTURE 7

Win+w

Signal Processing on Databases

Jeremy Kepner

Lecture 3: Entity Analysis in Unstructured Data

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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:

SQL

data

Database (sql):

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):		Server (http):		Database (sql):
	http put ⇄ http get	Apache Windows Server	SQL ⇄ data	SYBASE ORACLE IBM DB2 SQL Server MySQL
		Language: Java, php, perl, python, Ruby		
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

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.
- Great view. Massive data.

Future Web?

Game (data):

graphs ⇄ graphs

portal

Server (files):

lustre

graphs ⇄ graphs

portal

Database (triples):

BigTable

riak

Language:

D4M

Cassandra

HBASE

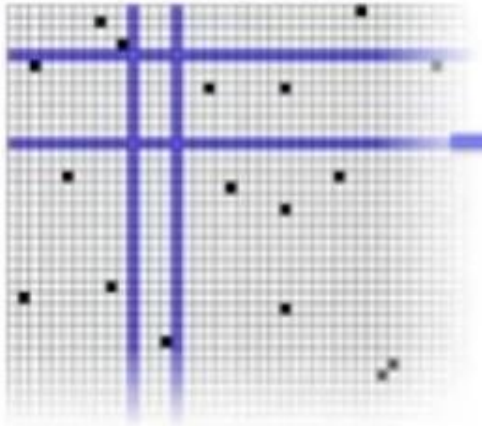
Client	Server	Database

- 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

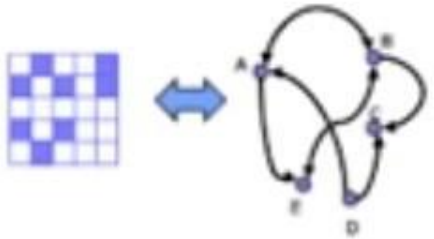
D4M

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…

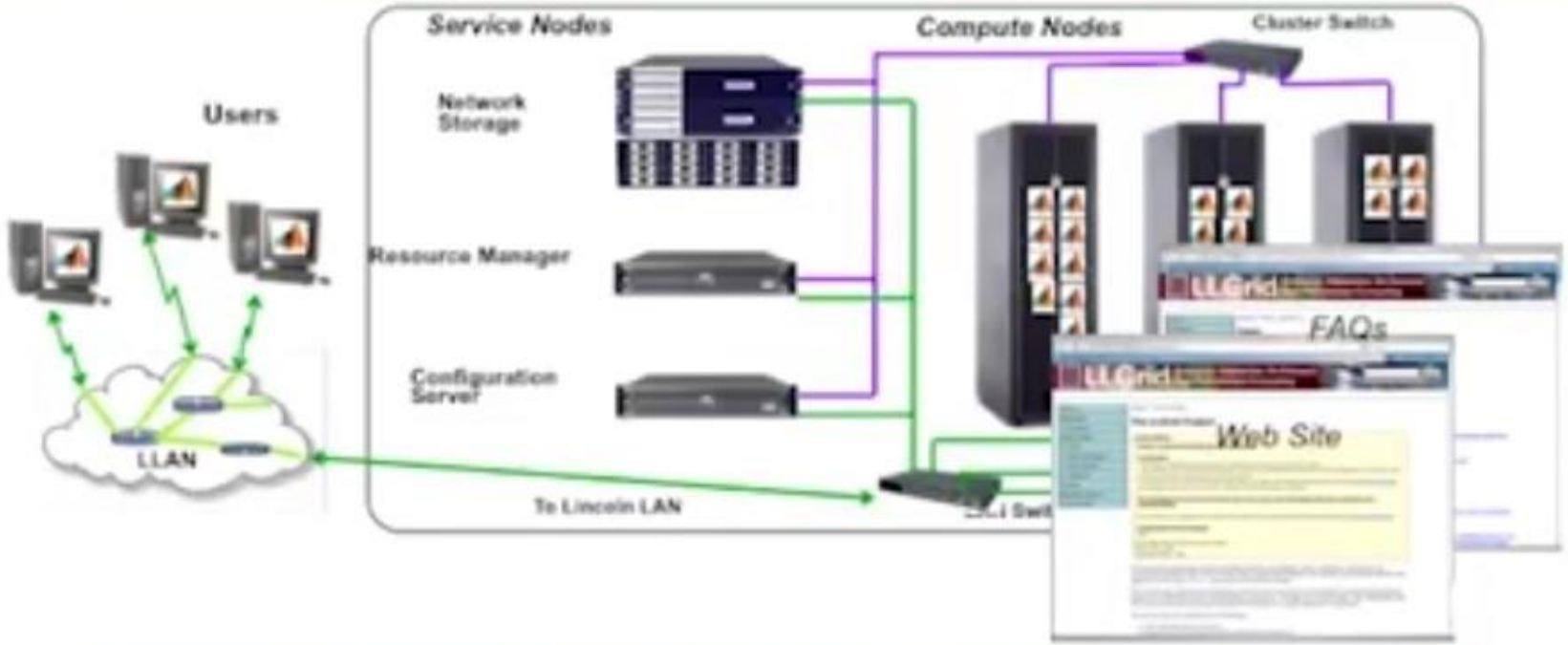
…for statistical signal processing or graph analysis in MATLAB

- 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?



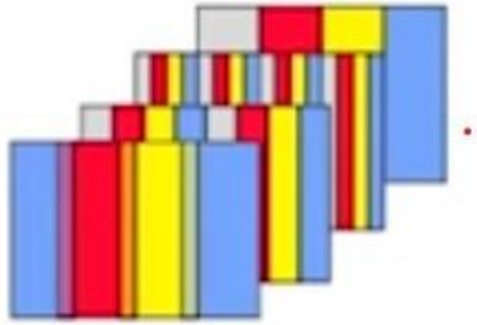
- LLGrid is a ~500 user ~2000 processor system
- World's only desktop interactive supercomputer
  - Dramatically easier to use than any other supercomputer
  - Highest fraction of staff using (20%) supercomputing of any organization on the planet
- Foundation of Supercomputing in Massachusetts

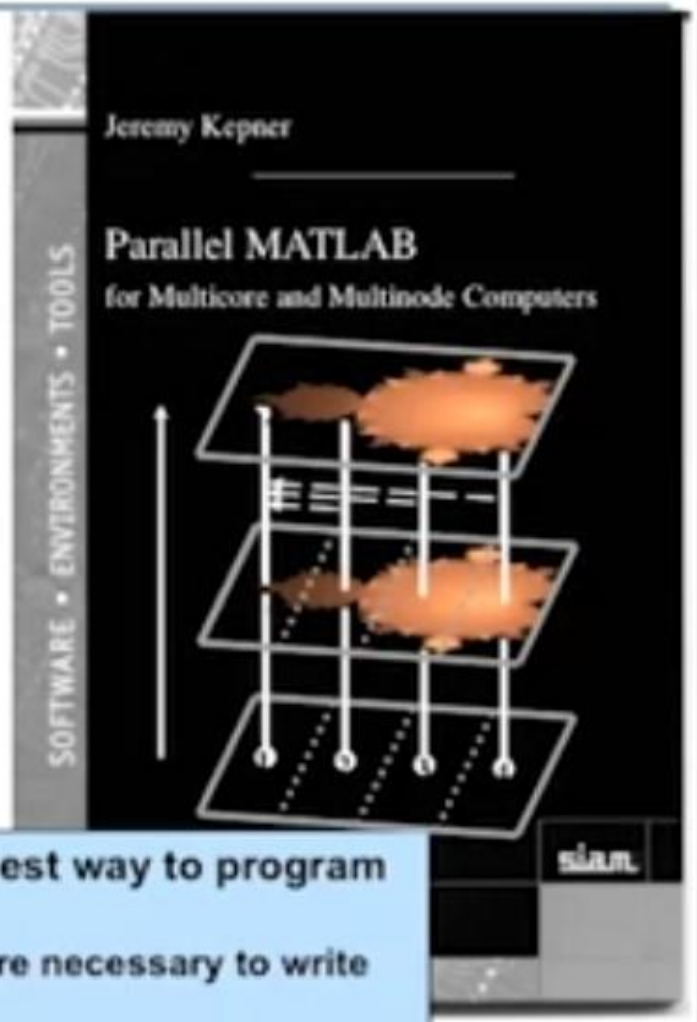
Why is LLGrid easier to use?

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



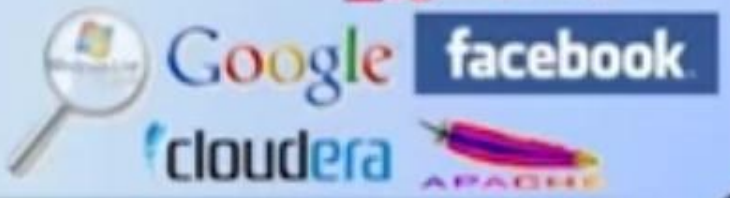


- Distributed arrays have been recognized as the easiest way to program a parallel computers since the 1970s
  - Only a small number of distributed array functions are necessary to write nearly all parallel programs
- LLGrid is the first system to deploy interactive distributed arrays

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

IaaS
- Interactive
- On-demand
- Elastic

LLGrid

Supercomputing

PaaS
- High performance
- Parallel Languages
- Scientific computing

PaaS
- Java
- Map/Reduce
- Easy admin

Big Data

accumulo

HBASE

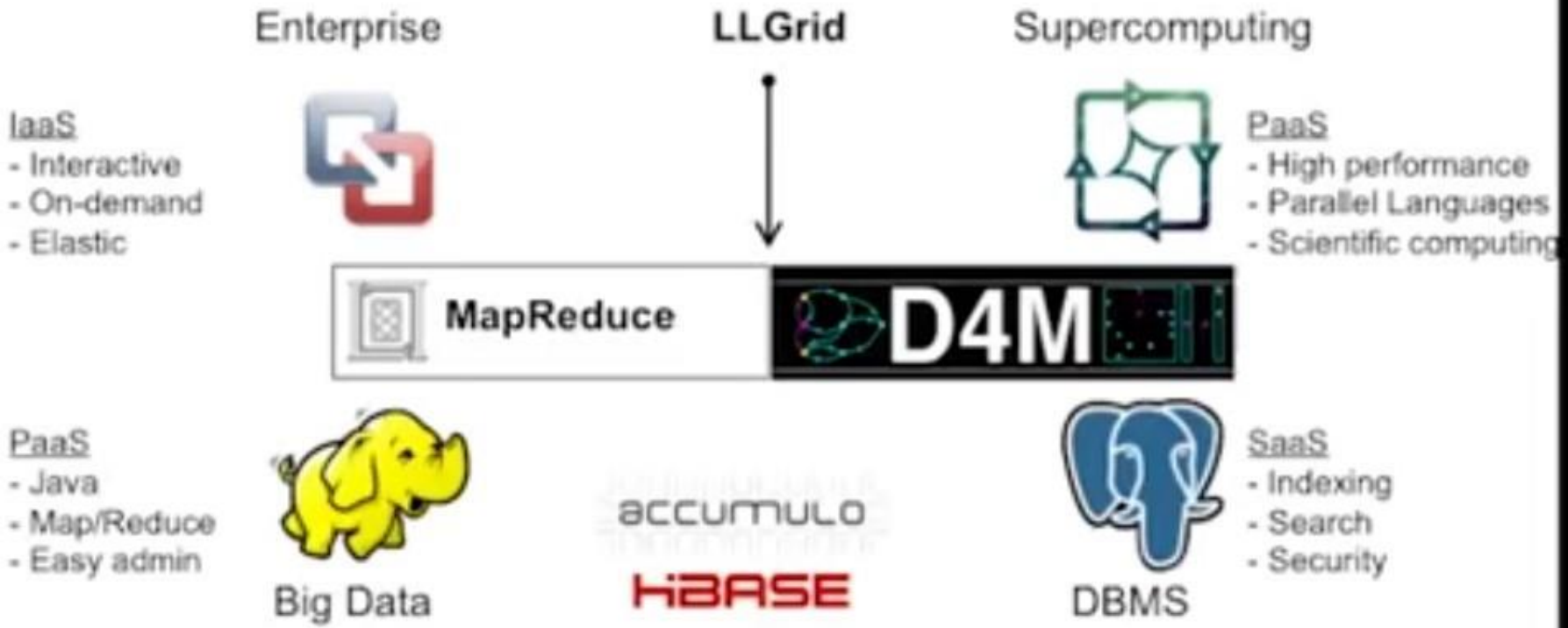
DBMS

SaaS
- 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

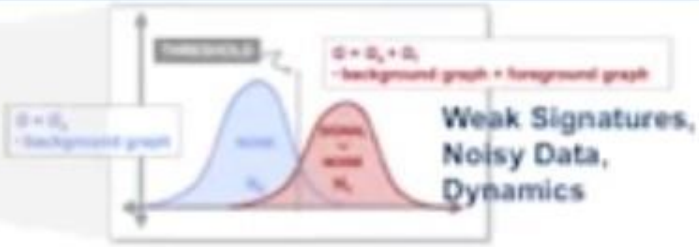


- **LLGrid MapReduce provides map/reduce interface to supercomputing**
- **D4M provides an interactive parallel scientific computing environment to databases**

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

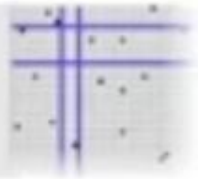
Big Compute + Big Data Stack

Novel Analytics for:
Text, Cyber, Bio



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

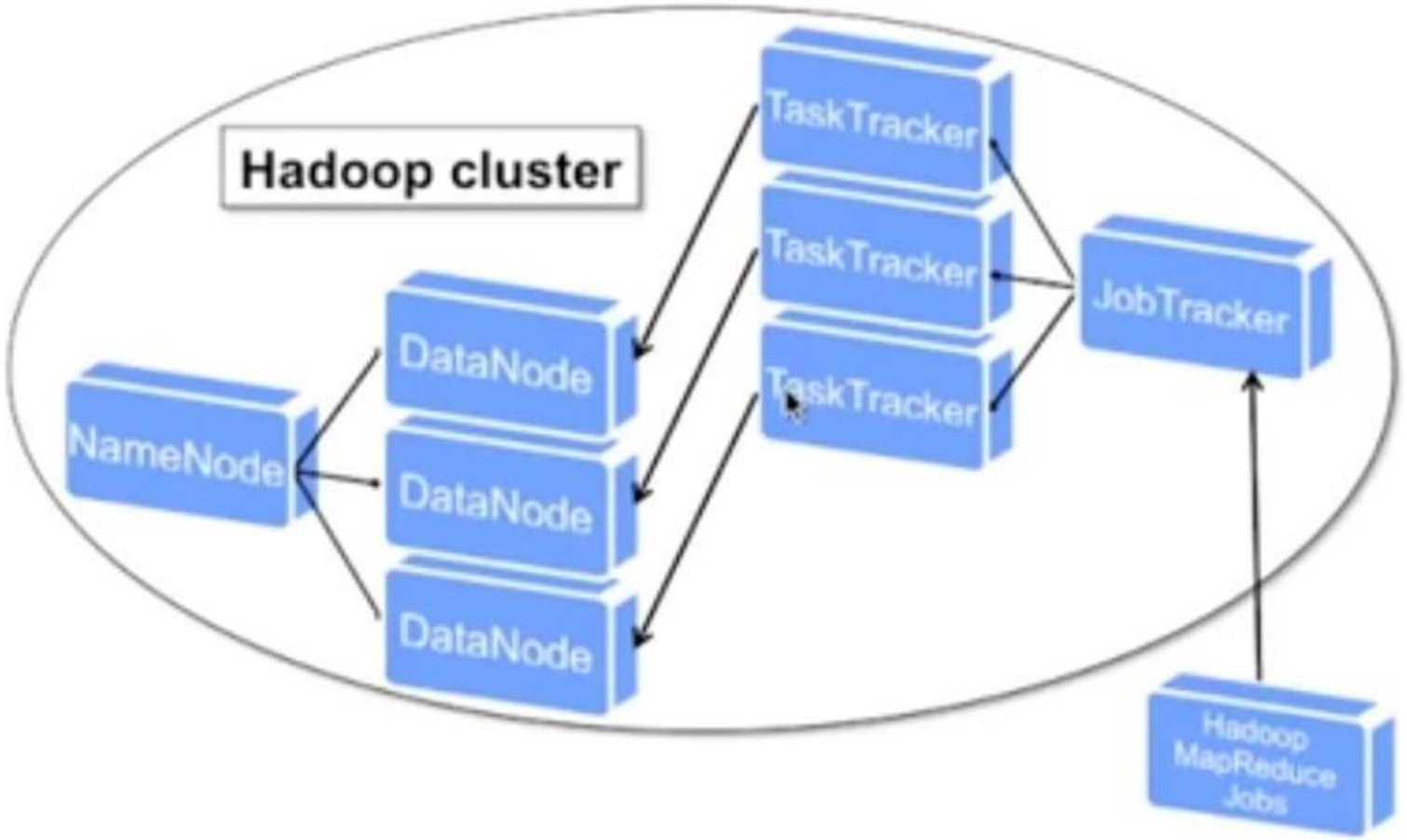
Distributed Database:
Accumulo/HBase (triple store)



High Performance Computing:
LLGrid + Hadoop

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

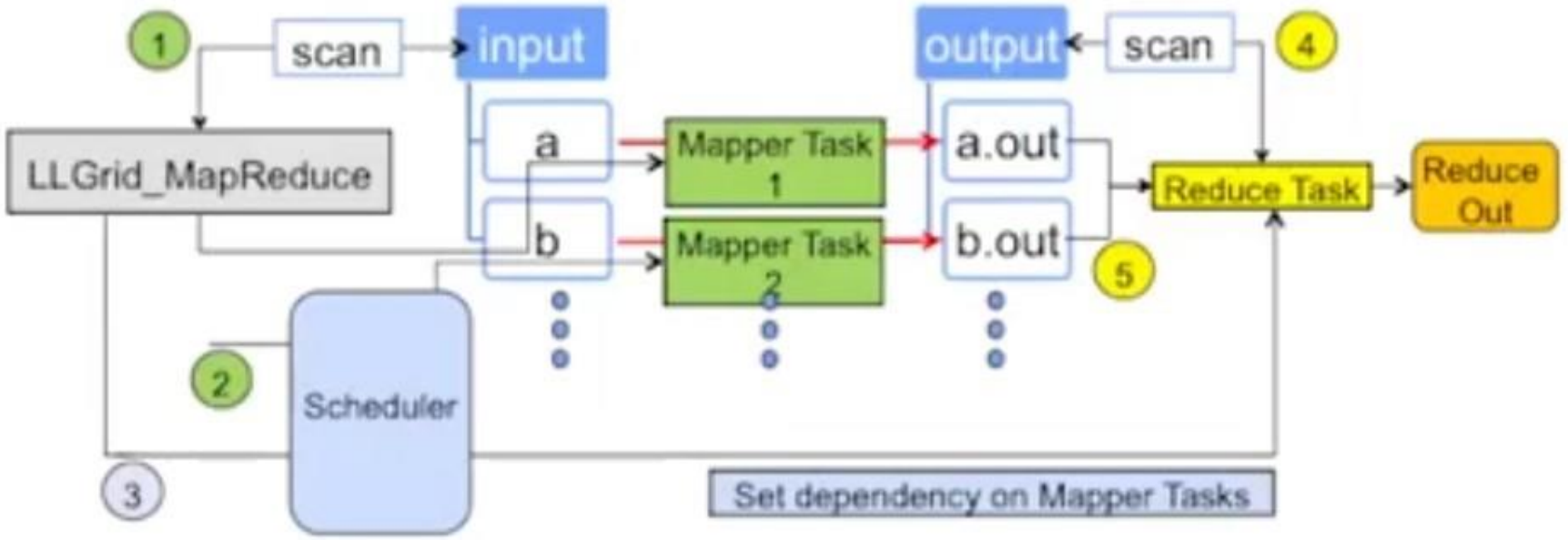
Hadoop Architecture Overview



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**

Multi-Dimensional Associative Arrays

- Extends associative arrays to 2D and mixed data types

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

or

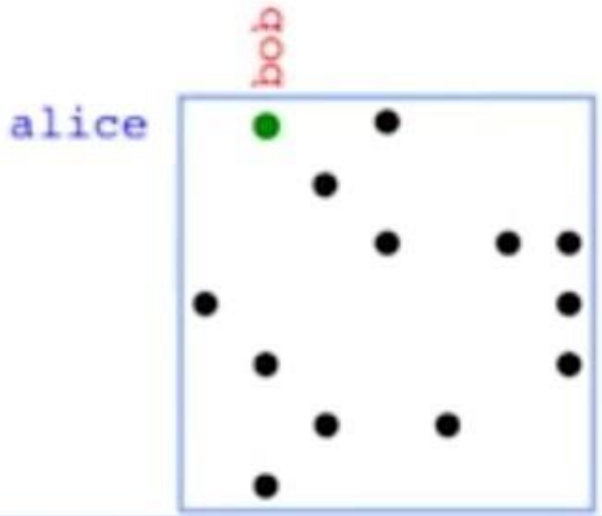
```
A('alice ','bob ') = 47.0
```

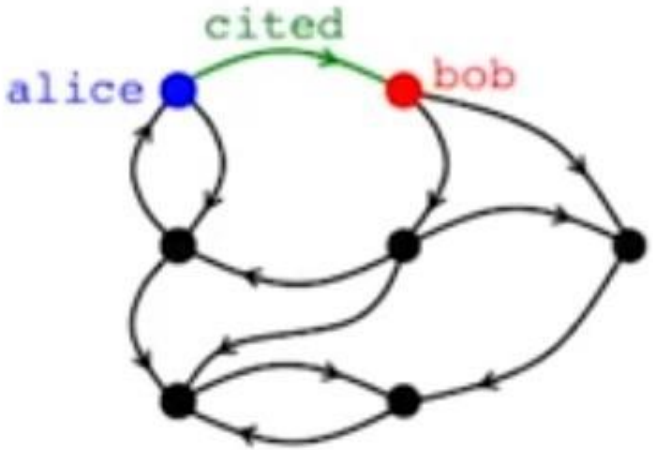
- Key innovation: 2D is 1-to-1 with triple store

```
('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

Triple Store Table: T

- 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
```

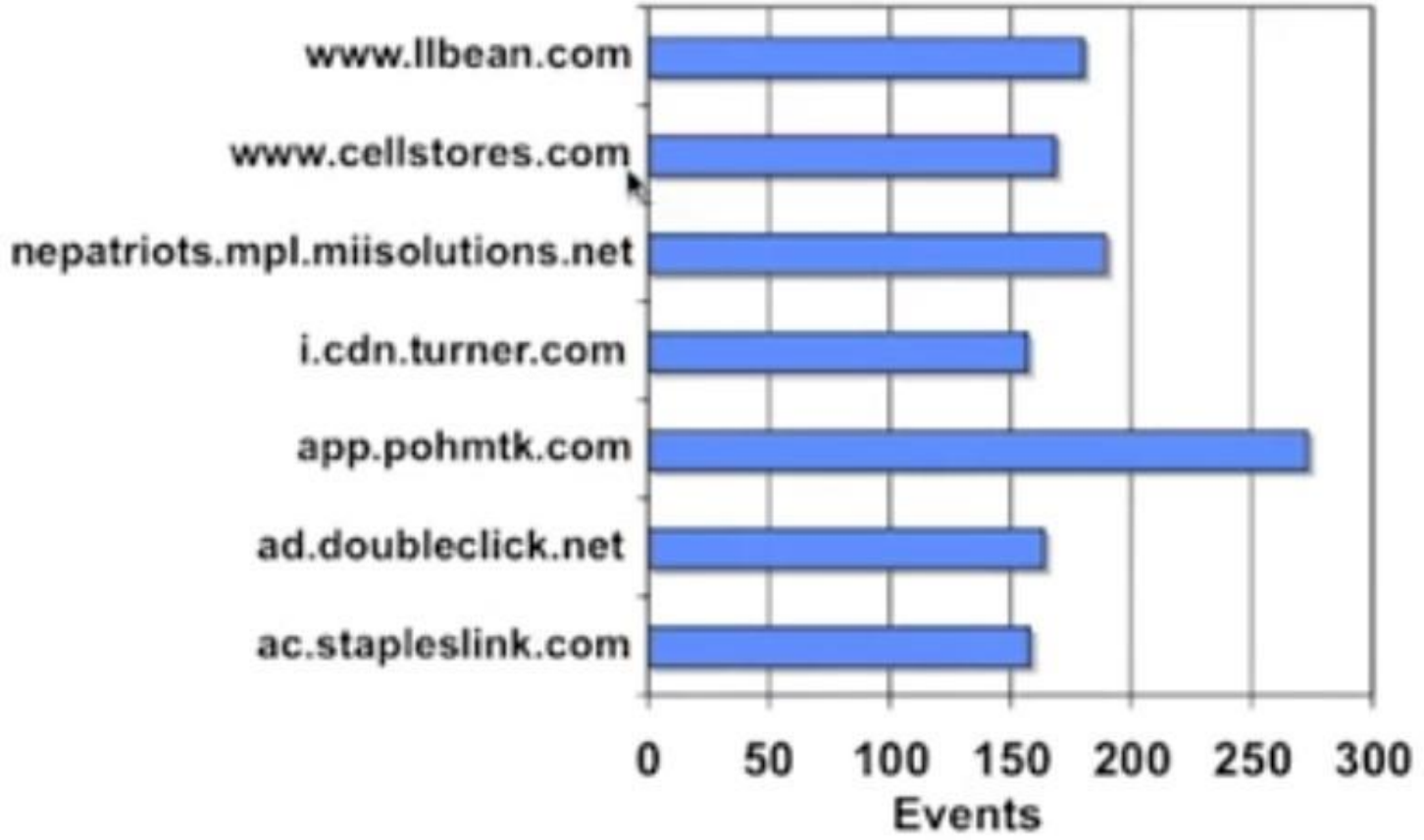
or

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

- **Find domains with many dest IPs**

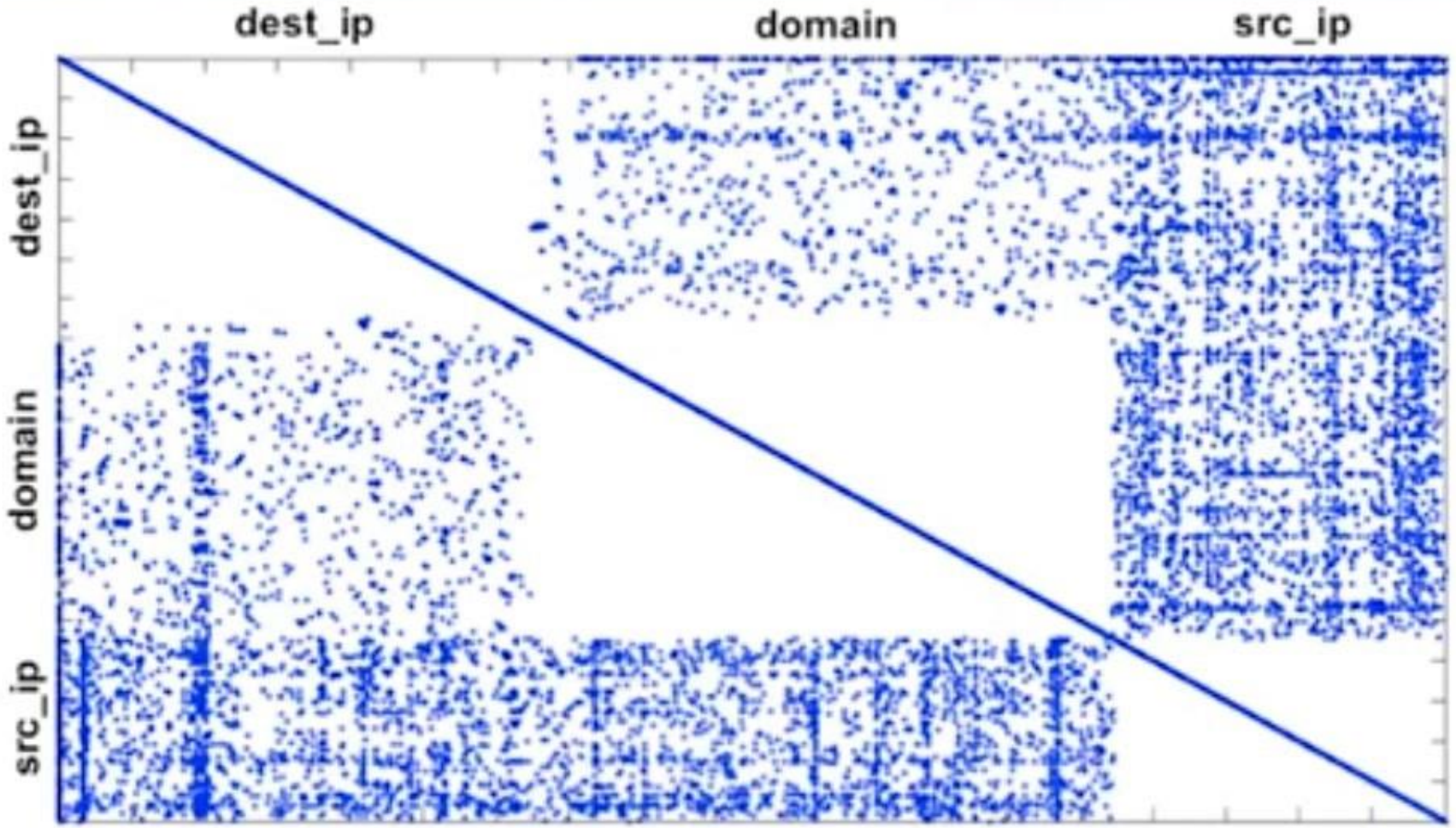
```
sum(double(logical(sqIn(A))),2) > 3
```


Count



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

Covariance

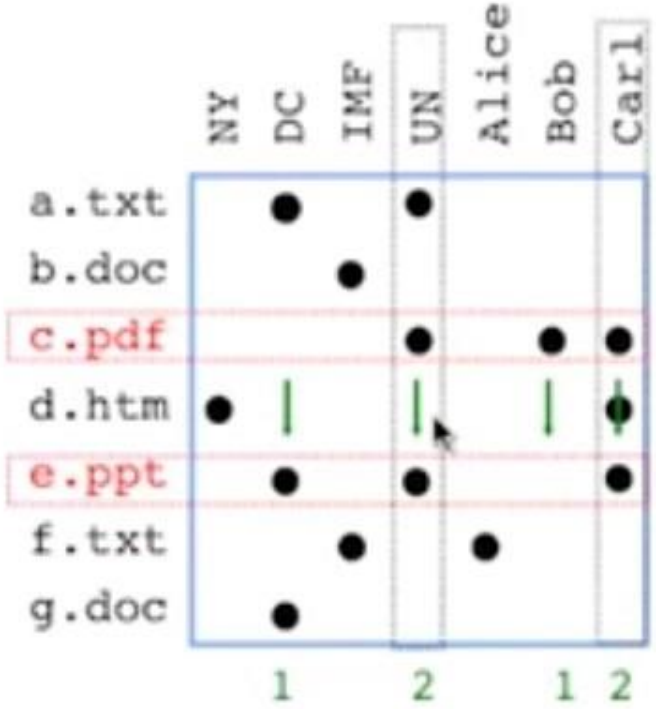


- Adjacency matrix a natural result of covariance calculation

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

$$A(x,y) : S^{N \times M} \rightarrow R$$

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

$$A(:,y_1) \,\&\, A(:,y_2)$$

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

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

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