The web is replacing the desktop

SDKs & toolkits are there

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What about the backend?

Image: Wikipedia user Calyponte

Two key concepts

- Processing 1000x more data doesn't have to be 1000x harder
- Cycles and bytes, not hardware, are the new commodity

Cloud computing is:

(Engineering definition)

Providing services on virtual machines allocated on top of a large physical machine pool

Cloud computing is:

(Business definition)

A method to address scalability and availability concerns for large scale applications

Cloud computing is:

(The big picture)

Democratized distributed computing

Outline

- Introduction
- Large-Scale Data Processing
- Cluster Management
- Conclusions

Outline

- Introduction
- Large-Scale Data Processing
  - MapReduce
  - The Google File System
  - BigTable
  - Hadoop
- Cluster Management
- Conclusions

What could you do…

…with 1000x as much data & CPU power?

- Scale your business to 1000x more users
- Gather statistics about every user click
- Improve recommendation systems
- Model better price plan choices
- Simulate 1,000,000 users of a system

Why can't you do it?

- Large-scale cluster reliability is hard!
  - Machines fail
  - Hard drives crash
  - Network goes down
  - Software bugs
  - Gremlins?
- Two tasks for two types of people
  - Designing reliable, scalable system architecture
  - Writing data processing algorithms

An old problem…

Image: Bill Bertram

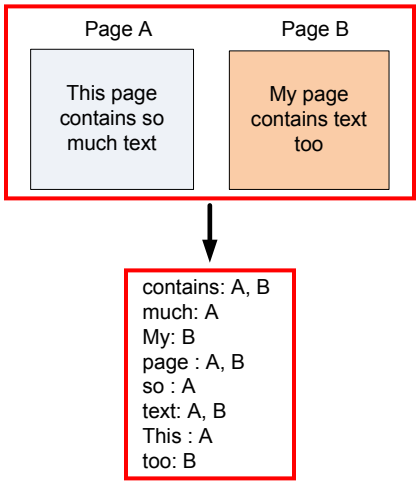
…At a larger scale

Image © Google, Inc.

MapReduce

- Developed at Google in 2003
- Divides *performing computation reliably* from *computing over large data*
- Provides reliable, scalable platform on which to develop distributed applications
- Simplifies programming model for distributed application writers
  - Data flow programming

Example use: Make an index

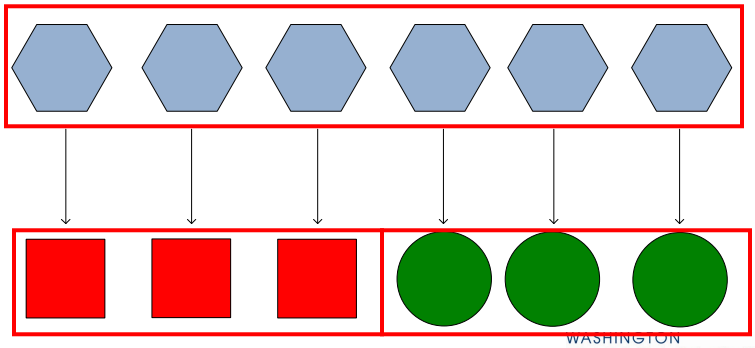


Algorithm:

1. For each page, get a list of all words on the page
2. For each word from (1), get list of pages on which it appears

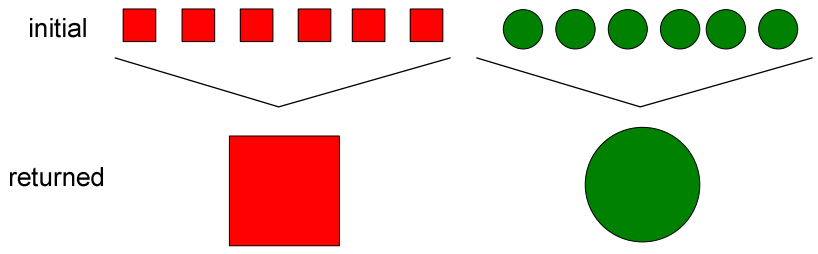
Map

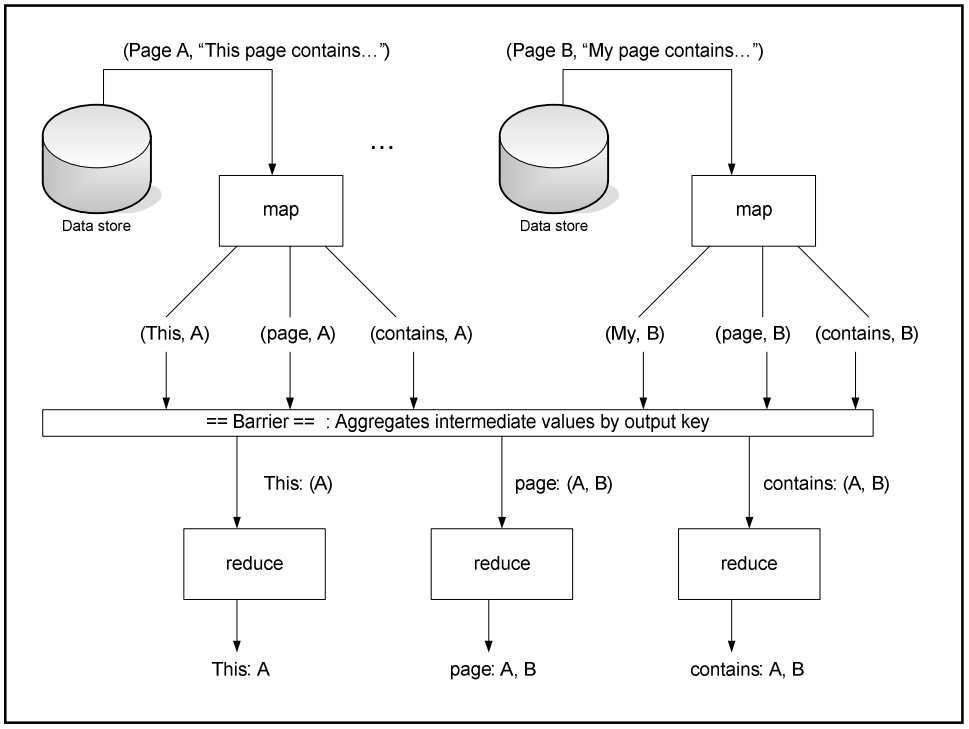
```
map  (in_key, in_value) ->
   (out_key, intermediate_value)
```



Reduce

```
reduce (out_key, intermediate_value list) ->
     out_value
```





Building the index

Page A

This page contains so much text

Page B

My page contains text too

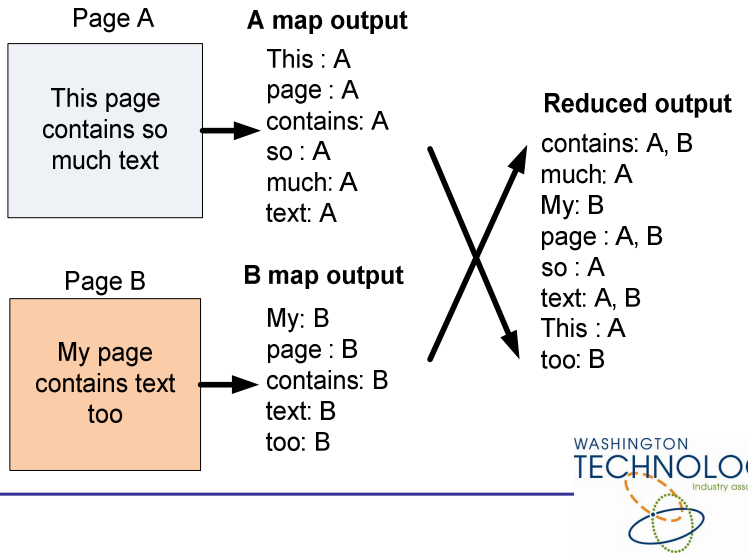
contains: A, B
much: A
My: B
page : A, B
so : A
text: A, B
This : A
too: B

Index: MapReduce

```
map(pageName, pageText):
    foreach word w in pageText:
      emitIntermediate(w, pageName);
    done

reduce(word, values):
    foreach pageName in values:
      AddToOutputList(pageName);
    done
    emitFinal(FormattedPageListForWord);
```

Index: Data Flow



Other applications

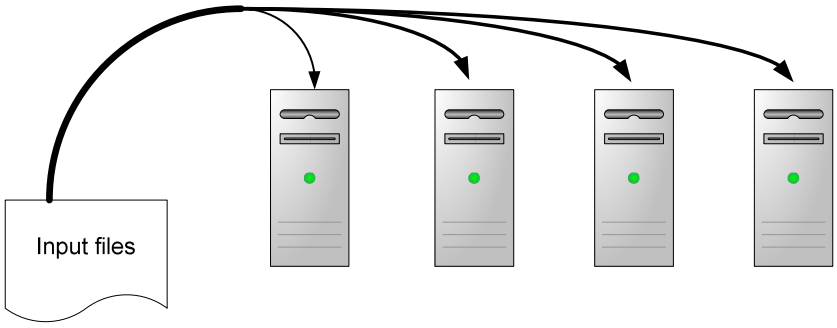
- Classifying instances; machine learning
- Log analysis: click streams, user trends
- Image processing
- A scalable implementation of your backend business logic

The Google File System

The distributed file system is what makes MapReduce work

- Data spread evenly throughout cluster
- Replicated 3x for redundant storage
- Master machine detects failures and rebalances data on the fly

Putting it together: active storage



Data automatically distributed to nodes at load time

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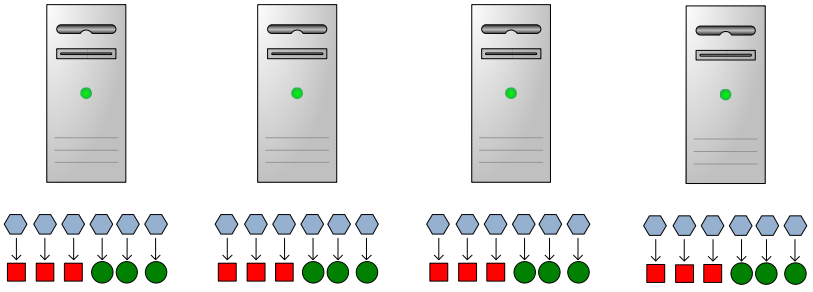
Automatic parallel processing



Data elements processed locally, in parallel

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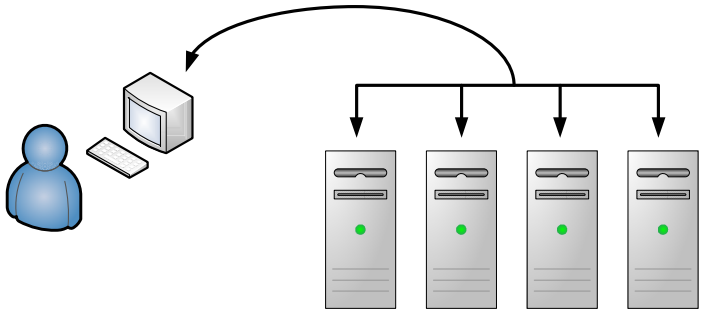
Distributed data, single volume



Output data is written to local disks, and forms a **single user-accessible volume**

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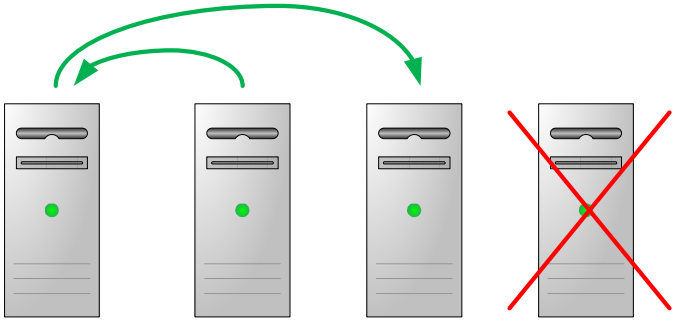
A self-healing system



Loss of nodes causes automatic data rebalance

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Adding structure

- GFS provides storage for very large files
  - But structure within files is still slow to use
- Organized database storage still valuable
  - How to get scalable storage and performance?

What does a database do?

- Stores large amounts of data
  - Individual “records” not too large
  - Many records stored per table
- Search over this data (SQL queries)
  - Individual record via index (fast)
  - Complicated joins of related information
- Consistent modifications (transactions)

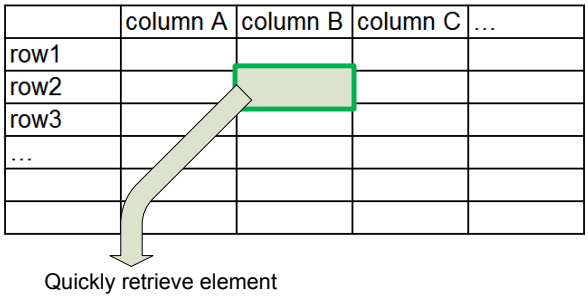
Web scale database problems

- Number of records gets *very* large
- Must be split across several machines
  - Must be stored reliably, redundantly
  - How to keep copies consistent?
- Must have fast access to individual elements, and be able to search it

BigTable

- A Google database layer
- Key idea: divorce organized storage from query system

Fast single-element access



- High-speed lookup of individual (row, column)
- Selects data needed by online applications

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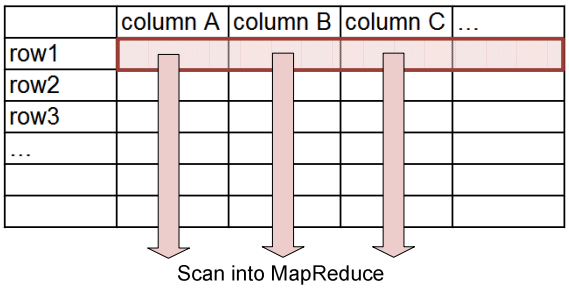
BigTable as a MapReduce input



- Each row is an input record to MapReduce
- MapReduce jobs can sort/search/index/query data in bulk

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BigTable conclusions

- BigTable provides large-scale storage, MapReduce provides query backend
- Stores immense amount of structured data
  - Uses Google File System for reliability
- Tradeoff: non-standard data access model

Hadoop

- Open source MapReduce + GFS + BigTable
- Java implementation
- Free for commercial use
- Official Apache Software Foundation project

Broad industry adoption

Flexible interoperability

- C++/Python: Pipes/Streaming
- Distributed database: HBase
- Machine learning: Mahout
- Performance tracking: Ganglia
- Development environment: Eclipse
- Hosting: Amazon Web Services

Benefits of Hadoop

- Open source MapReduce, GFS, BigTable
- Clean programming abstractions
  - Allows rapid prototyping of large-scale computation
- Scalable active storage infrastructure
  - Programs for 10 GB of data work for 10 TB
- Reliable storage of dynamic data
  - 3x replication, continuous monitoring

Outline

- Introduction
- Large-Scale Data Processing
- Cluster Management
  - Clouds & Virtualization
  - Amazon Web Services
  - Rightscale
  - AWS + Hadoop
- Conclusions

Constrained Resources

- Large-data applications are I/O bound
  - Hard drive speed is the limiting factor
- Availability of RAM is 2nd level concern
- Raw CPU speed not usually a factor

Typical hardware profile

- "Commodity" server-class machines
  - Think performance/watt or per $$
- 4 processor cores (not fastest available)
- 4-8 GB RAM
- 2x500 GB SATA hard drives

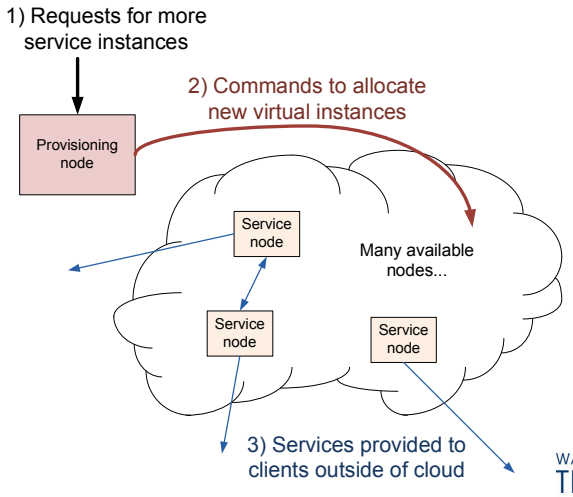
Traditional service architecture

- Expensive upfront, maintenance costs
- Requires many types of resources
  - Machines, power, cooling, bandwidth…
- Does not scale on demand
- Not easily reconfigurable
  - Adding virtualization helps with this

What is a cloud?

- Virtualized server pool
- Reconfigures to provide different service profiles on demand
- Individual node providing service is unimportant

Clouds: high-level



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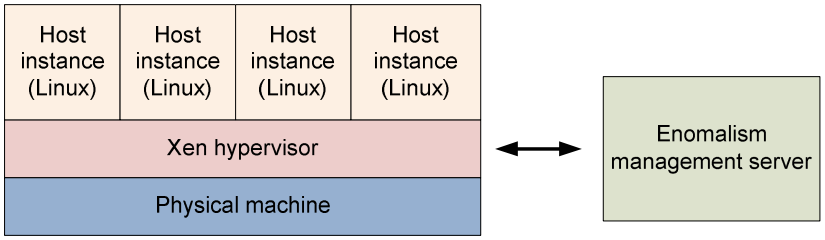
Server architecture



Xen®

enomalism virtualized server management

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Amazon Web Services

- EC2: Elastic Compute Cloud
- S3: Simple Storage Service
- SQS: Simple Queue Service
- SDB: Simple Database

aws.amazon.com

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Elastic Compute Cloud

- Provides on-demand processing power
- From $0.10/instance*hour + bandwidth
- Virtual machine images with dynamic or static IP addresses

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EC2 Templates

- EC2 node configuration stored as *Amazon Machine Image* (AMI)
- 100s of stock AMIs available
  - Generic Linux distributions
  - Hadoop configurations
  - Web server / database installations
- Existing AMIs can be customized & saved for later reuse

Simple Storage Service

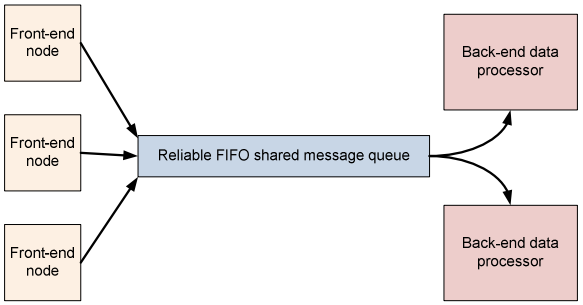
- Virtually infinite storage capacity
- Cost: $0.15/GB*month + bandwidth
  - Free high-speed access to/from EC2 nodes
- Provides permanence layer when EC2 nodes aren't running

Data Security

- Secure data transfer via SSL
- Encrypted storage possible in S3

Simple Queue Service

- Efficient, reliable load distribution layer
- Pay by the message



Simple Database Service

- High availability large-store database
- Provides simple SQL-like language
- Designed for interactive/online use

System reliability

- Geographic server diversity through *availability zones*

Broad existing user base

Powerset
NATURAL LANGUAGE SEARCH

ABACA

37signals

SmugMug

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Highlight: SmugMug

- Flickr-style online photo hosting
- Entirely stored on S3

They do not own any hard drives!

SmugMug

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A “web service?”

- Resource provisioning access via SOAP
  - Scriptable client-side tools
  - Not actually exposed on the web by AWS

Web services for the rest of us

RIGHT SCALE

- Web-based interface to AWS
  - Provisioning commands
  - Monitoring & status
- Parameterizable startup scripts

www.rightscale.com

(Rightscale Demo)

RIGHT SCALE

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Automatic scalability

- Real power of Rightscale is in monitoring
- Scales instances based on demand
- Provides backend reliability in virtual environment

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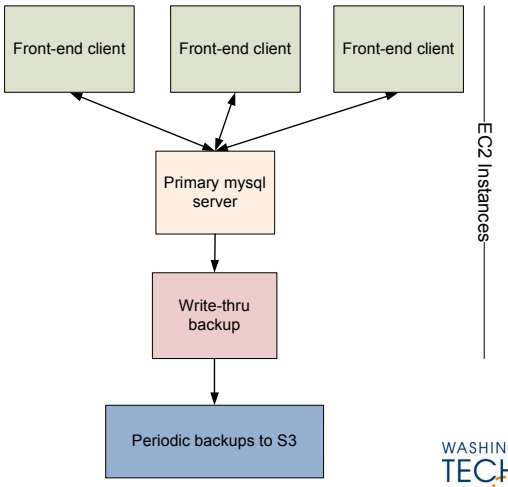
mysql setup in EC2/S3



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Google App Engine

- Integrated cloud computing platform
- Compute resources with GFS- and BigTable-backed storage
- Limited preview now; check back soon!

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Using AWS with Hadoop

- Hadoop runs on EC2 nodes
  - Templates defined for several versions
- Permanent results storable in S3
- EC2-served frontend retrieves results
  - Published via static IP address

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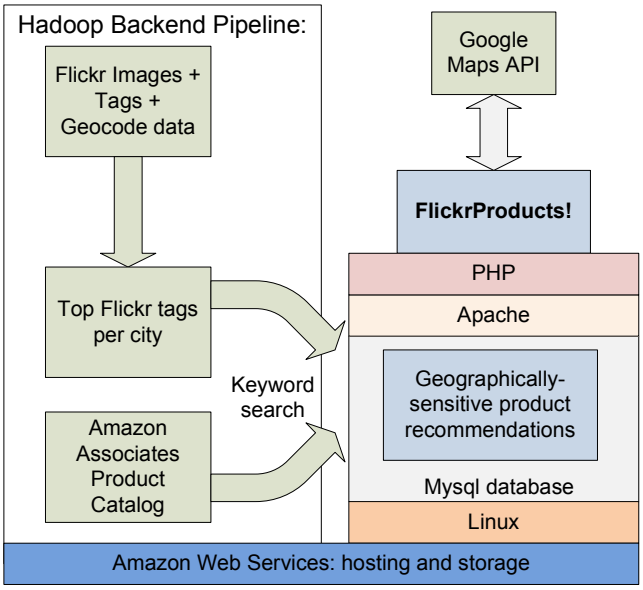
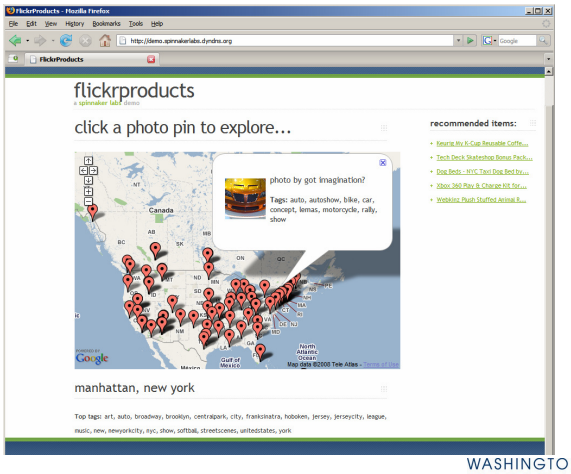
Putting it together: FlickrProducts



FlickrProducts Tour



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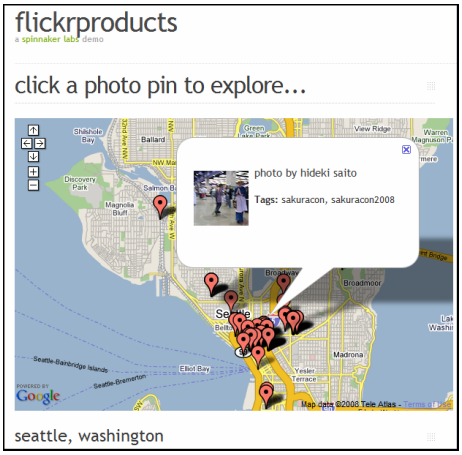
Images in context on the map



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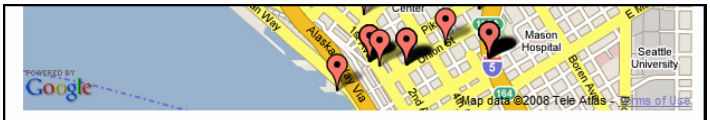
Top tags listed per city



seattle, washington

Top tags: anime, barca, con, convention, cosplay, eyefi, geotagged, kerriesbirthday, march, ontheboards, party, ratcityrollergirls, rcrg, rollerderby, rollergirls, rollerskating, s4b1, sakuracon, sakuracon2008, unitedstates

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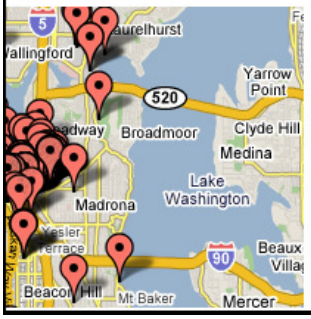
Recommendations from Amazon



recommended items:

+ Hello Kitty Jewelry Box
+ Full Metal Panic! DVD
+ Fruits Basket Cosplay Cap
+ Japanese "Domo-kun" T-shirt

Add to Shopping Cart

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Demo technical points

- Public Amazon, Flickr APIs for input data
- Hadoop pipeline entirely in Java
- Frontend: mysql + PHP + Javascript
- Full system hosted on AWS EC2
  - VM Image and database backed by S3
- Rightscale management dashboard
- **Conception-to-demo time: two days.**

Conclusions

- Powerful new abstractions for large-scale data processing systems
  - Scalable, reliable, available
  - Support rapid development
- Large managed server pools available
  - Low overhead
  - Eliminate management headaches
  - Grow and shrink according to need

Questions?

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