



Carnegie
Mellon
University

Data and Application

Tutorial of Parameter Server

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About me

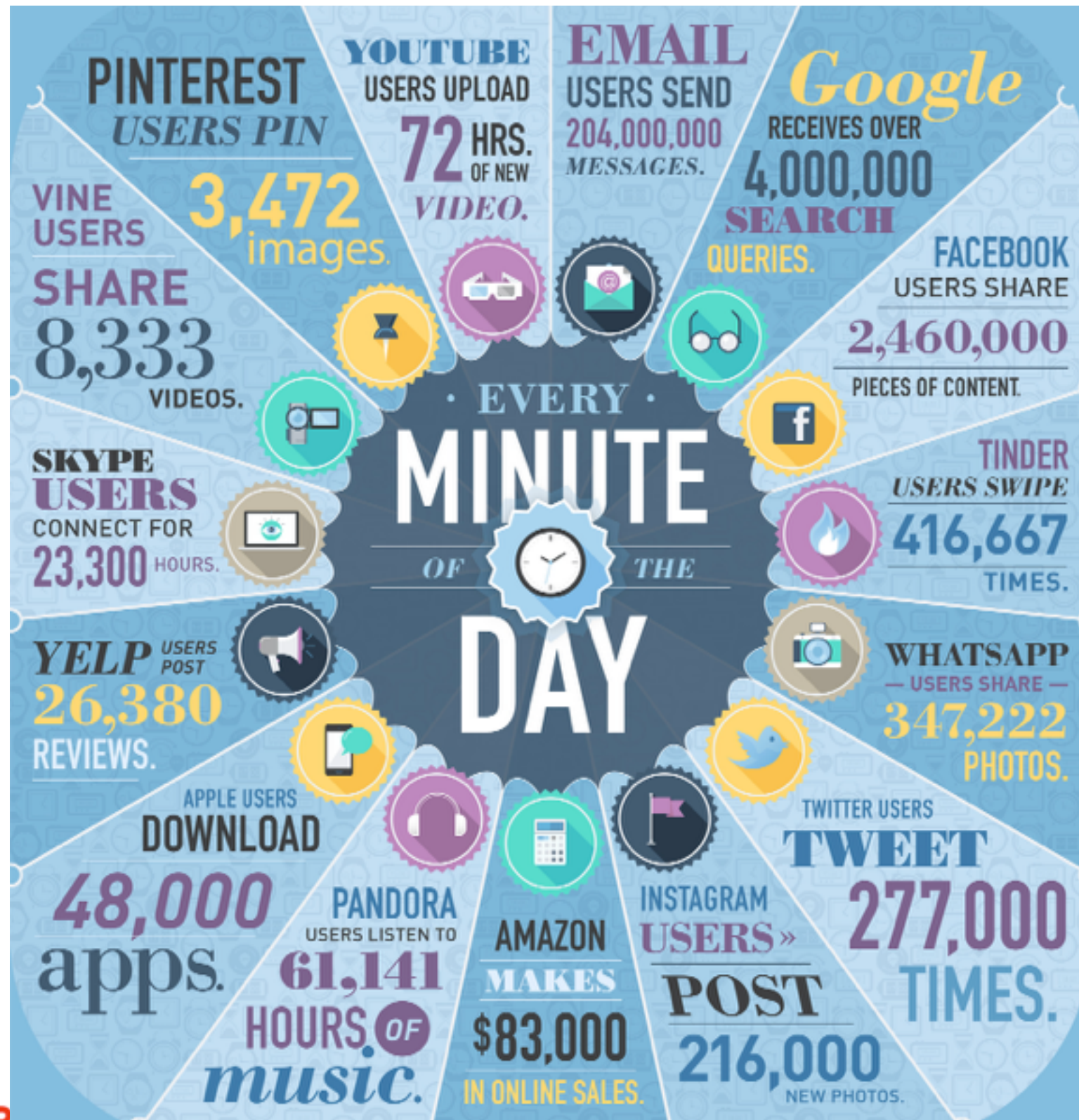
- ♦ Ph.D student working with Alex Smola and Dave Andersen
 - ★ large scale machine learning theory, algorithm, application, and distributed system
- ♦ Senior architect at Baidu
 - ★ the largest search engine at China, >60% market share
 - ★ working on distributed machine learning systems for computational ads

About this tutorial

- ✦ Focus on the design and implementation of large scale machine learning systems
- ✦ Parallel and distributed algorithms
- ✦ Several coding exercises
- ✦ Provide real datasets and machines

Application & Data

There are lots of data



- ◆ Text
- ◆ Images
- ◆ Voices
- ◆ Videos
- ◆ All about user activities: personalization

Data are sparse

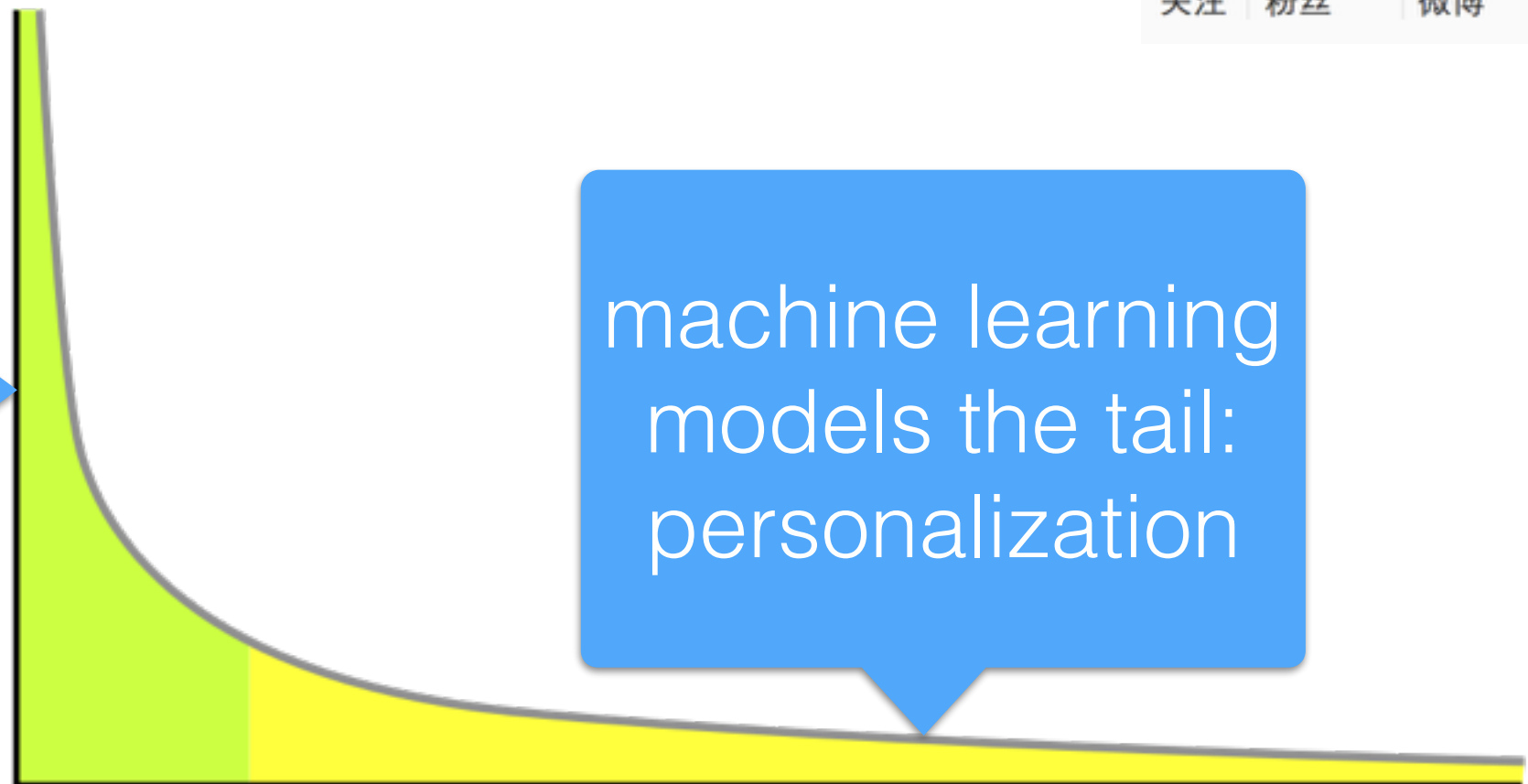
- ♦ Most categories have only few
- ♦ Most users are not so active

not true, indeed more active than Alex :)



simple
statistic tools
model the
head well

machine learning
models the tail:
personalization



Online Advertising

- ✦ The major revenue source of internet search companies
- query: “flower delivery” results from baidu, google, bing

Baidu 百度 新闻 网页 贴吧 知道 音乐 图片 视频

鲜花速递

中国鲜花速递网,全国领先的鲜花网站鲜花速递!!

中国鲜花网
Xianhua.CN
1 HOUR
全国销量领先

中国鲜花速递,完美服务,顶尖信誉,鲜花速递,免费牌!1-3小时送达全国,鲜花速递,方便快捷,货到付款
鲜花速递导航 - 畅销鲜花楼 - 生日蛋糕 - 品牌保证
www.xianhua.ac.cn 2014-07 - 推广

鲜花速递 中国名品鲜花网-24小时在线订花 - 鲜花速递服务
浪漫爱情 卡通花束 生日花束 全天24小时在线订花
商业花篮 节日果篮 生日蛋糕 全国市区免费配送
www.mphua.com 2014-07 - 推广

✦ 鲜花速递 中国鲜花礼品网 3小时送花服务
鲜花速递-中国鲜花礼品网,销量连续5年全国领先,3小时送达全国900多城
鲜花网 邮政鲜花速递 订鲜花 鲜花快递 鲜花配送
www.hua.com 2014-07 - 推广

鲜花速递实体店连锁鲜花店 鲜花速递1-3小时送达
鲜花速递实体店配送,鲜花速递市区免费送货,鲜花速递可以先送花后付款.
鲜花网 鲜花预定 鲜花配送 毕业鲜花 买鲜花
www.ijhua.cn 2014-07 - 推广

flower delivery

Web Maps Shopping Images Videos More

About 15,200,000 results (0.21 seconds)

1-800-FLOWERS® - 1800Flowers.com
Ad www.1800flowers.com/ 4.3 ★★★★★ advertiser rating
International Flower Delivery is Simple with 1-800-FLOWERS.COM!
“Excellent” – Stella Service
Popular Destinations. Best Selling Flowers
Birthday Balloons. Shop By Country.

Flowers to USA for \$19.99 - ProFlowers.com
Ad www.proflowers.com/ 4.2 ★★★★★ advertiser rating
Send Flowers to Your Loved Ones. 100% Satisfaction Guaranteed.

\$19.99 Flower Delivery - Same Day Delivery To
Ad www.fromyouflowers.com/Flower+Delivery 4.4 ★★★★★ advertiser rating
“Best Value Flowers” - CBS News

flower delivery

46,100,000 RESULTS Any time

Ads related to flower delivery

Flower Delivery - \$19.99 | FromYouFlowers.com
www.FromYouFlowers.com
Same Day Delivery Flowers - Hand Delivery In 4 Hours!
fromyouflowers.com is rated ★★★★★ on Bing (143602 reviews)
Birthday Flowers & Gifts Same Day Delivery
\$19.99 Flowers Sympathy & Funeral

ProFlowers® - \$19.99 - Send Flowers for any Occasion.
www.ProFlowers.com/Flowers
“Best Value” -Wall Street Journal.
Flowers - Free Shipping Roses
Flowers - Daily Deals Birthday Flowers

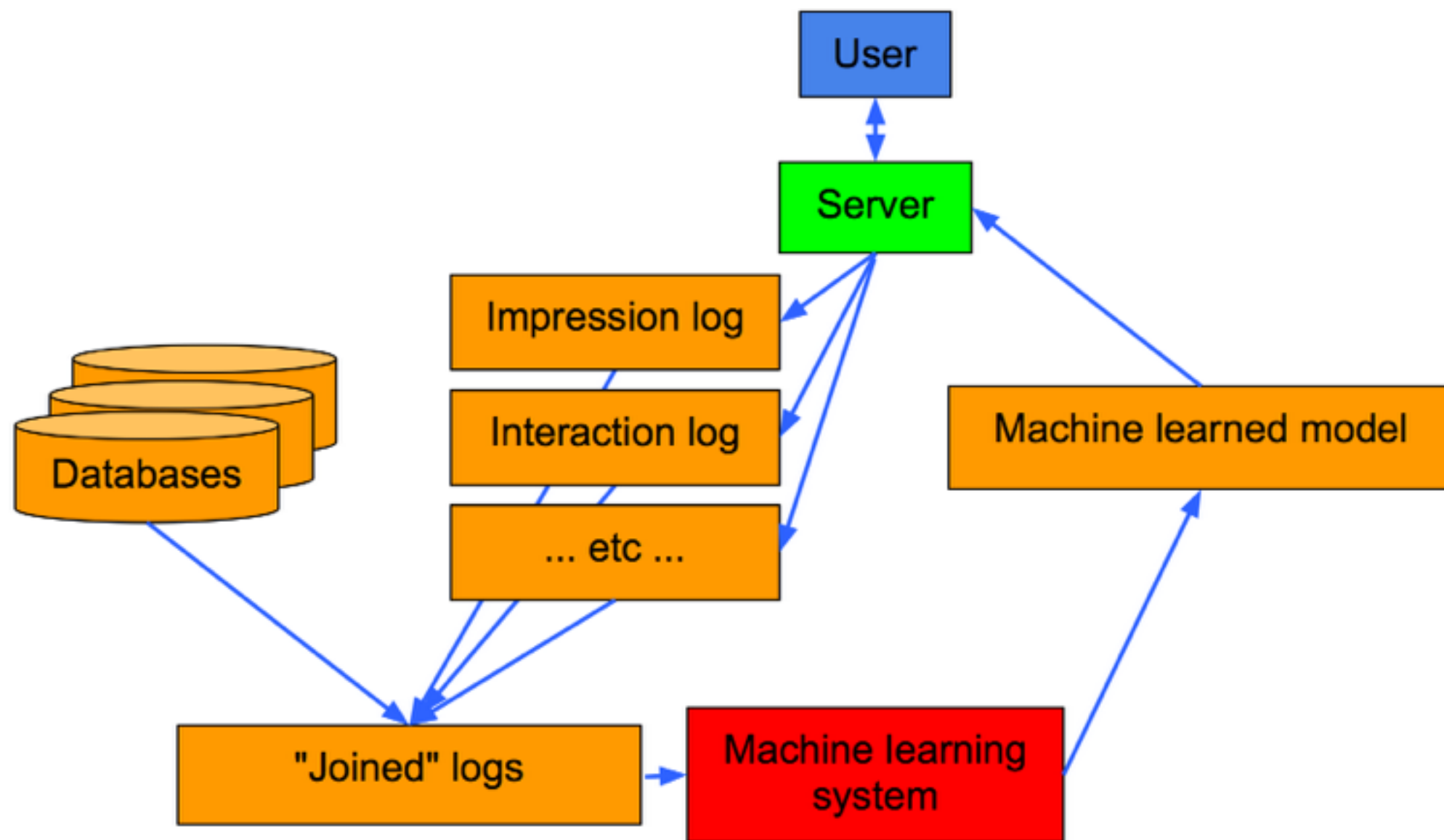
Flower Delivery - 50% Off - Fresh Flowers \$17.49 - Order
www.bloomstoday.com/FlowerDelivery
Same Day Flower Delivery Guaranteed
Save on Flowers Today Flowers Under \$39.99
Birthday Flowers

FTD® Flowers for \$19.99 | FTD.com
www.FTD.com/FlowerDelivery
Up to 33% Off Stunning FTD® Flowers Hand-Delivered by a Local Florist!

Computational Advertising

- ♦ Search companies charge advertisers if their Ads were clicked by users
- ♦ Display position is the scarce resource
- ♦ Ads are ranked by
$$p(\text{click} \mid \text{Ad}, \text{user}, \text{scene}) \times \text{bid_price}(\text{Ad})$$
- ♦ bid prices are given (studied by electronic mechanism design)
- ♦ our goal: predict the click-through rate

System architecture



from Google Sibyl

Machine Learning Approach

- ◆ Represent {Ad, user, scene} as a feature vector x , let y (clicked or not clicked) be the label, then model $p(y|x)$

- ★ A common way

$$p(y|x, w) = \frac{1}{1 + \exp(y\langle x, w \rangle)}$$

- ★ then learn w by logistic regression
- ◆ Also increasing interests on deep learning

Feature Engineering

- ✦ Feature engineering is the most effective way to improve the model performance
 - ★ even still true for deep learning
- ✦ Easy way to add domain knowledge into the model
- ✦ Often contain multiple feature groups
 - ★ three major sources: ads, users, advertisers

N-grams

1-800-**FLOWERS**® - 1800**Flowers**.com

Ad www.1800flowers.com/ ▼ 4.3 ★★★★★ advertiser rating

International Flower Delivery is Simple with 1-800-**FLOWERS**.COM!

“Excellent” – Stella Service

- ♦ uni-gram: international, flower, delivery, ...
- ♦ bi-gram: international flower, flower delivery, ...
- ♦ tri-gram: international flower delivery, ...
- ♦ for short text, even desirable generate all possible n-grams, then filter out unimportant ones

Style

Bold text

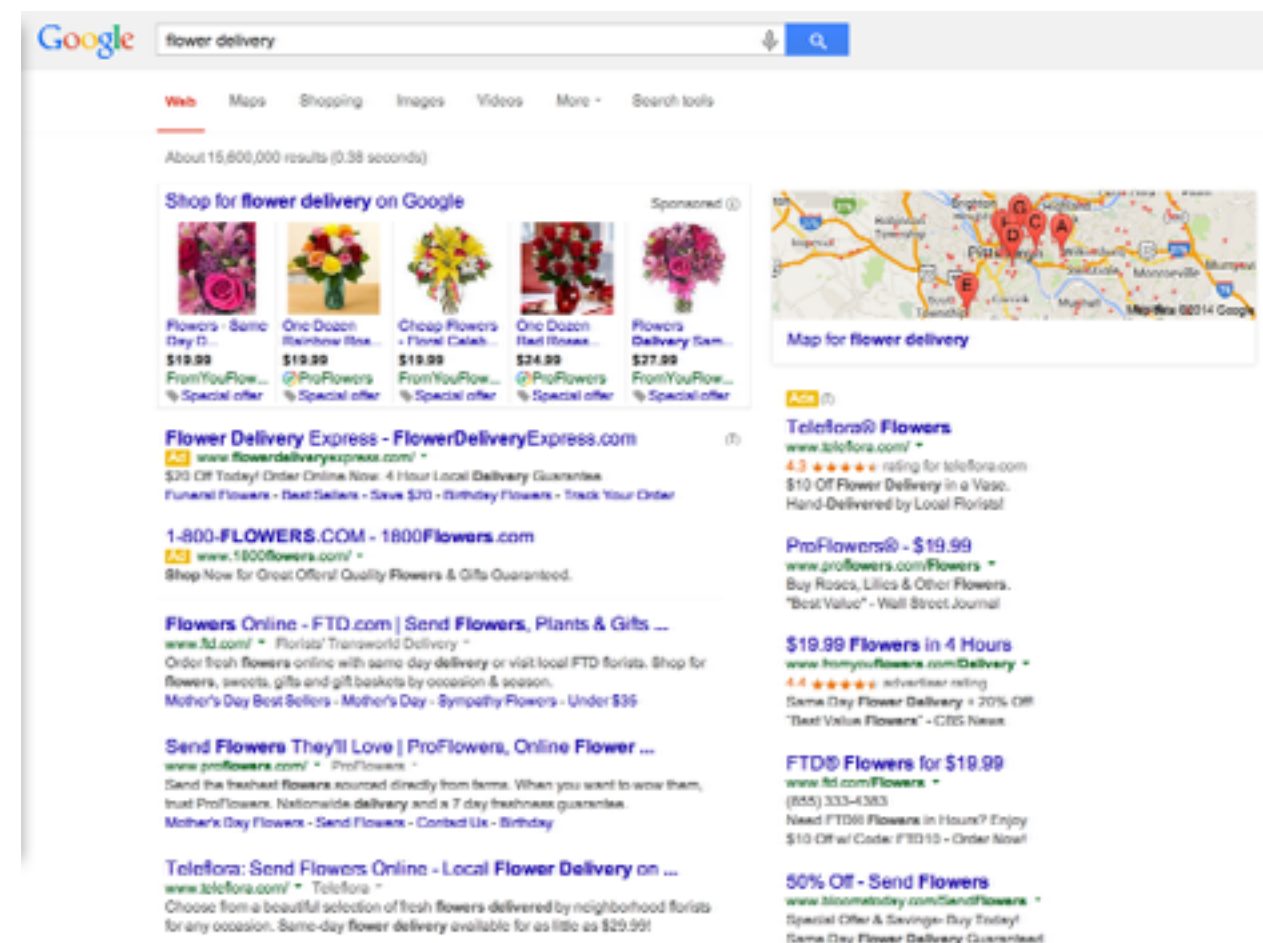
1-800-FLOWERS.COM - 1800Flowers.com

Ad www.1800flowers.com/ ▼

Shop Now for Great Offers! Quality Flowers & Gifts Guaranteed.

Layout

Images



Personalization

- ◆ Users profile
 - ★ gender, age, location, ...
- ◆ Advertiser profile
 - ★ category, reputation, ...
- ◆ Session
 - ★ a sequence of activities

Feature combination

- ◆ Given two feature groups
 - ★ $\{(a, 1), (b, 0)\}$
 - ★ $\{(A, 0), (B, 1)\}$
- ◆ Produce a combination group
 - ★ and: $\{(aA, 0), (aB, 1), (bA, 0), (bB, 0)\}$
 - ★ or: $\{(aA, 1), (aB, 1), (bA, 0), (bB, 1)\}$
- ◆ Approximate the polynomial kernel, but much more efficient
- ◆ Guide by domain knowledge or heuristic search

Google
Search

Google
Display
Network

HOW DOES GOOGLE MAKE OVER
\$10 BILLION A DAY
ADVERTISING?
the Economy!

2 trillion ads
in one year

Impressions are
the total number of
ads displayed

Daily Ad
IMPRESSIONS
per day in Q3 2012

AVERAGE
COST PER CLICK
in Q3 2012

vs Q2 2012
% of change

-16.5%

\$0.53

5.6
BILLION

24.2
BILLION

\$0.35

-18.2%

vs Q2 2012
% of change

vs Q2 2012
% of change

-12.4%

3.47%

AVERAGE
DAILY CLICKS
in Q3 2012

AVERAGE
CLICK THRU RATE
in Q3 2012

0.18%

+13.8% vs Q2 2012
% of change

% of change from Q2 2012

+21.6%

193.2
MILLION

44.7
MILLION

+29.1%

AVERAGE
CONVERSION RATE
in Q3 2012

4.68%

AVERAGE NUMBER OF
DAILY CONVERSIONS

Completed Sales, Leads Generated, Etc. in Q3 2012

5.63%

10.9
MILLION

2.1
MILLION

Data Scale of Ad-ctr

- ♦ Only 1 year search log produces 2 trillions examples
 - ★ sub-sampling? not always works because of the personalization
- ♦ Feature size = #ngram + #users + #sessions + #combination
 - ★ often at the same scale of #samples
- ♦ A training task some years ago

```
Sun Sep 23 [REDACTED] global # of instances [120,746,552,096]
Sun Sep 23 [REDACTED] global # of features [60,801,353,282]
```

Industry Dataset Size

- ♦ 100 billions of samples
- ♦ 10 billions of features
- ♦ 1T—1P training data

Training data



>5 years ago

Product	Examples	Compressed Raw data	Training data	Compression	Features per example	bytes per feature
A	59.9B	9.98TB	2.00TB	4.99x	54.9	0.67
B	7.6B	2.67TB	0.71TB	3.78x	94.9	1.07
C	197.5B	66.66TB	15.54TB	4.29x	77.7	1.11
D	129.1B	61.93TB	17.24TB	3.59x	100.57	1.46

Where to store the data

- ♦ Lots of disks
- ♦ Fail at any time

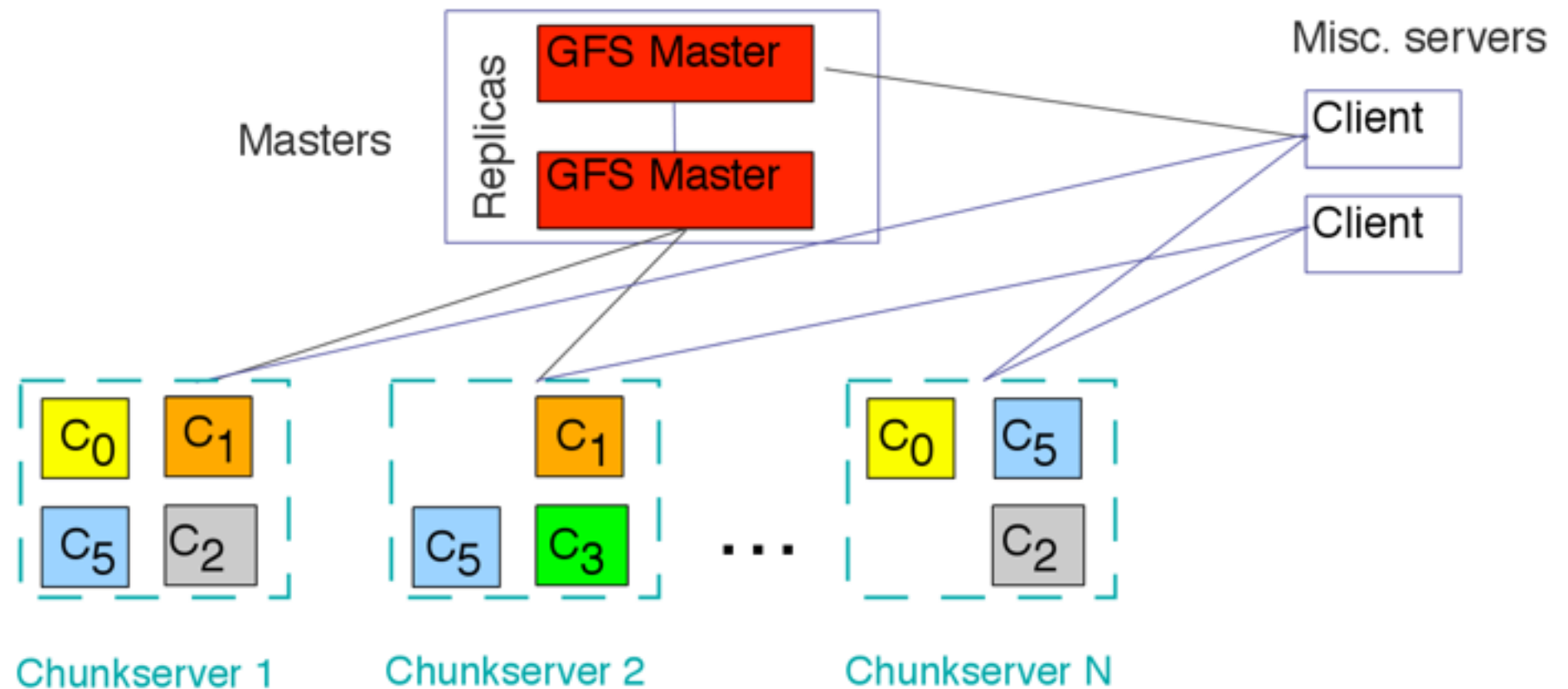


Access patterns

- ✦ Files are large 100MB—10GB
- ✦ Sequential read and append

```
1100958974 Jun 30 17:17 part-13073.gz
1102681642 Jun 30 17:18 part-13074.gz
1102654752 Jun 30 17:18 part-13075.gz
1099726070 Jun 30 17:18 part-13076.gz
1101590533 Jun 30 17:18 part-13077.gz
1100016199 Jun 30 17:19 part-13078.gz
1100637016 Jun 30 17:19 part-13079.gz
1102254166 Jun 30 17:20 part-13080.gz
1103309165 Jun 30 17:21 part-13081.gz
1101572961 Jun 30 17:21 part-13082.gz
1100632933 Jun 30 17:22 part-13083.gz
1101068910 Jun 30 17:22 part-13084.gz
1099448455 Jun 30 17:22 part-13085.gz
1100856891 Jun 30 17:23 part-13086.gz
1101677645 Jun 30 17:23 part-13087.gz
1102511398 Jun 30 17:23 part-13088.gz
1099531212 Jun 30 17:24 part-13089.gz
1100965668 Jun 30 17:24 part-13090.gz
1100877289 Jun 30 17:24 part-13091.gz
1100353449 Jun 30 17:25 part-13092.gz
1102797472 Jun 30 17:25 part-13093.gz
1100592927 Jun 30 17:25 part-13094.gz
1100954490 Jun 30 17:26 part-13095.gz
```

Google File System



- ♦ Data are replicated
 - ★ write success only if all replicas are done
- ♦ Request data:
 - ★ ask master for the location
 - ★ ask chunk server for the data
- ♦ New generations: Colossus

HDFS

- ✦ Open source implementation of GFS
- ✦ operations:
 - ★ `hadoop fs -ls, -get, -put, -head, -cat, ...`
 - ★ `libhdfs: C API`
 - ★ `mount` to local filesystem
- ✦ A little bit slower than GFS (personal experience)
- ✦ Large delay
 - ★ `hadoop fs -ls /xxx` (8000 files)
- ✦ Sometimes reading the training data uses more times than training

```
real    0m16.992s
user    0m3.905s
sys     0m0.287s
```