Flexible Tables

Where SQL meets semi-structured data

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Who are we?

And if we do all that, how’re we so small?

We’re a start-up driving the biggest Silicon Valley tech company

Academic roots

- Founded in 2005 by Mike Stonebraker (MIT)
- “C-Store: A Column Oriented DBMS” (VLDB 2005)
- “The Vertica Analytic Database: C-Store 7 Years Later” (VLDB 2012)

Acquired by Hewlett-Packard in 2011

- HP was having trouble; we were busy being awesome so they left us alone
  - They gave us lots of sweet hardware, though
- HP’s now recovering; they’re (very actively) asking us how we do it

Small group of highly competent engineers

- About 40 core developers today
- Small teams; big challenges; lots of freedom

What do we enable?

What’s the big deal?

Our tools power the world’s big analytics shops

What if you knew, and could query in seconds…

- Every stock trade ever?
- Every phone call ever?
- Every tweet?
- Every gene in your genome?

Clusters of hundreds of machines, with tens of petabytes of data.

You can’t do that with MySQL.

Whose users want sub-second response times on real queries.

You can’t do that with Hadoop.

Vertica users

```
SELECT HEAT_MAP_IMAGE(lat, lon)
  OVER (PARTITION BY country)
  FROM tweets
  WHERE SENTIMENT(text) < -1;
```

Yep, we do that.

What is Vertica?

“One cluster to rule them all…”

Speed

+

Scale

+

Simplicity

“MPP OLAP RDBMS”

- SQL Database for Real-time Analytics
- Runs on commodity x86_64 hardware
- MPP Columnar Architecture – scales to PBs!
- Easy to setup and use
- Extensive Ecosystem of analytic tools

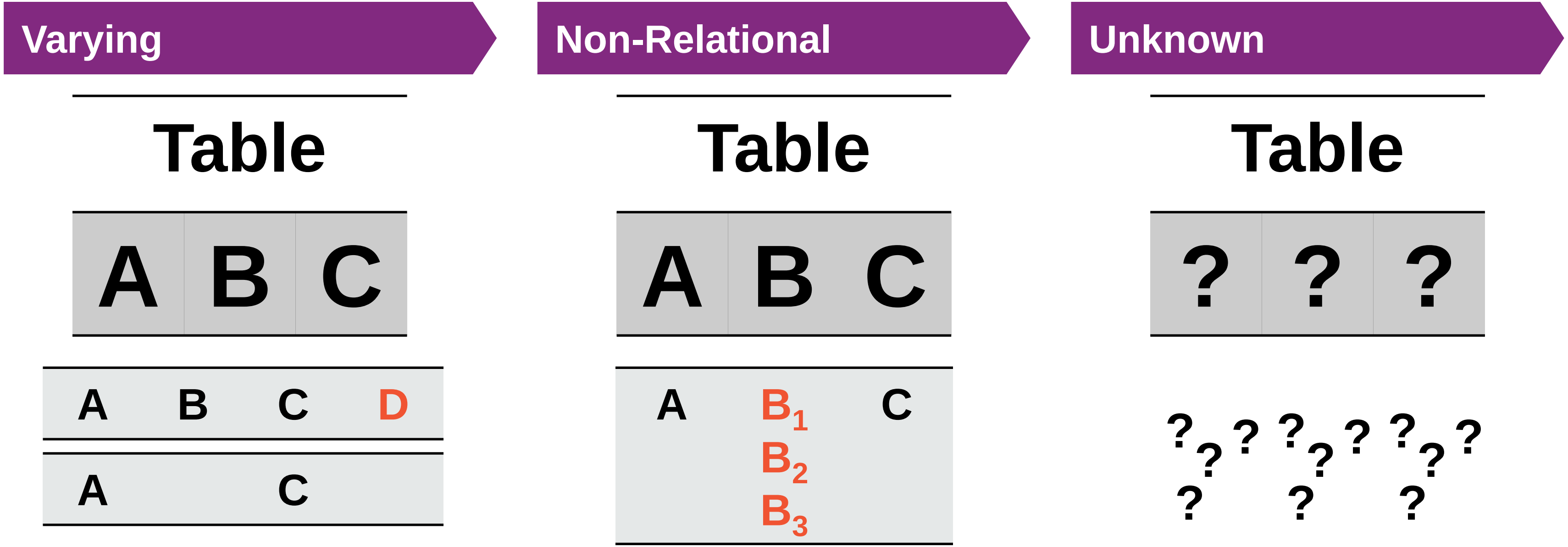
High Level Goals for Flexible Tables

- SQL Databases must
  - Ingest semi-structured data easily
  - Query it naturally
- Queries should be input-format agnostic (*i.e.*, vanilla SQL against relational tables)
- Vertica shows good results along this path

What is Semi-Structured Data?

A very “RDBMS” point of view

Data that has structure, but that structure is:



Varying

Table

A B C

A B C D

A C

Non-Relational

Table

A B C

A B_1 B_2 B_3 C

Unknown

Table

? ? ?

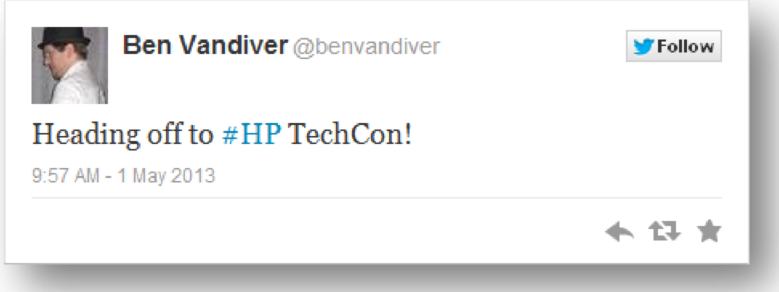
? ? ? ? ? ?
? ? ?
? ? ?

A Semi-Structured Data Example:

Are German tweets longer than English tweets?

Tweets: Raw Data

“Tweet child of mine”



Ben Vandiver @benvandiver

Heading off to #HP TechCon!

9:57 AM - 1 May 2013

Twitter Public Streaming API

https://stream.twitter.com/1.1/statuses/sample.json

Contains tweets:

```
{"filter_level":"medium","contributors":null,"text":"Heading off to #HP TechCon!",
"geo":null,"retweeted":false,"in_reply_to_screen_name":null,"truncated":false,"lang":"en","entities":{"symbols":[],"urls":[],"hasht
ags":[{"text":"HP","indices":[15,18]}],"user_mentions":[]},"in_reply_to_status_id_str":null,"id":329595489773309952,"source":"web",
"in_reply_to_user_id_str":null,"favorited":false,"in_reply_to_status_id":null,"retweet_count":0,"created_at":"Wed May 01 13:57:43
+0000 2013", "in_reply_to_user_id":null,"favorite_count":0,"id_str":"329595489773309952“,"place":null,
"user":{"location":"Cambridge,
MA","default_profile":true,"statuses_count":1,"profile_background_tile":false,"lang":"en","profile_link_color":"0084B4","id":148363
627,"following":null,"favourites_count":0,"protected":false,"profile_text_color":"333333","description":"A database
guy.","verified":false,"contributors_enabled":false,"profile_sidebar_border_color":"C0DEED","name":"Ben
Vandiver","profile_background_color":"C0DEED","created_at":"Wed May 26 14:22:29 +0000
2010","default_profile_image":false,"followers_count":12,"profile_image_url_https":"https://si0.twimg.com/profile_images/3596493897
/a4056576ec72b18a6087213f46080eeb_normal.jpeg","geo_enabled":false,"profile_background_image_url":"http://a0.twimg.com/images/theme
s/theme1/bg.png","profile_background_image_url_https":"https://si0.twimg.com/images/themes/theme1/bg.png","follow_request_sent":nul
l,"url":null,"utc_offset":null,"time_zone":null,"notifications":null,"profile_use_background_image":true,"friends_count":4,"profile
_sidebar_fill_color":"DDEEF6","screen_name":"benvandiver","id_str":"148363627","profile_image_url":"http://a0.twimg.com/profile_ima
ges/3596493897/a4056576ec72b18a6087213f46080eeb_normal.jpeg","listed_count":0,"is_translator":false},"coordinates":null}
```

and delete markers:

```
{"delete":{"status":{"user_id":178172685,"id":257897002996727808,"user_id_str":"178172
685","id_str":"257897002996727808"}}}
```

Using a Relational Database

“Old skool”

Define Schema

```
CREATE TABLE tweets(
  text varchar(~~140~~) (2000)
  “user.lang” varchar(10)
  …
);
```

Query

```
SELECT “user.lang”,
       AVG(LENGTH(text))
  FROM tweets
 GROUP BY “user.lang”;
```

Load Data

- Save tweets to disk
- Parse the JSON with Python to pull out the desired output columns into delimited format
- COPY tweets(text, “user.lang”) FROM ‘/path/to/parsed.json’

Pros and Cons

+ Easy to query

- Tricky to pick schema

- Awkward to load

Hadoop / Pig

“Going whole hog NoSQL”

Define Schema

- No need

Query

- Write some Pig:

```
register hdfs://…/user/benchmark/piggybank.jar
tweets = load 'hdfs://tweets.json' using JsonLoader() as (m: Map[]);
twt_r1 = foreach tweets generate m#'text', m#'user';
twt_r2 = foreach twt_r1 generate LENGTH($0), $1#’lang’ as m;
twt_r3 = group twt _r2 by $1
avg_lengths = foreach twt_r3 generate $1as lang, AVG($0) as text_len;
avg_lengths_ordered = order avg_lengths by text_len desc;
dump avg_lengths_ordered;
```

Load Data

- Save tweets to disk
- “cp” directly into HDFS, as with a file copy

Pros and Cons

+ No schema definition

+ Easy to load

- Trickier to query

- Degraded performance

Alternative SQL approach: JSON in DB

“Passing the buck”

Define Schema

```
CREATE TABLE tweets(
  contents VARCHAR(4096)
);
```

Load Data

- Save tweets to disk
- Break on JSON record boundaries
- COPY tweets(contents) FROM ‘/path/to/parsed.json’

Query

```
SELECT json_value(contents,’user.lang’),
 AVG(LENGTH(json_value(contents,’text’))
FROM tweets
GROUP BY json_value(contents,’user.lang’);
```

Pros and Cons

+ Minimal schema definition

+ Simpler to load

- Query exposes JSON storage

Database Principles

“Here I stand…”

SQL is declarative:

Specify the what, database determines how

Agnostic of storage:

Same SQL, if DB is row-store, column-store, compressed, loaded fixed-width or delimited, …

New approach: Flexible Tables

“Look Ma, no columns!”

Define Schema

```
CREATE FLEX TABLE tweets();
```

Load Data

- Save tweets to disk
- COPY tweets() FROM ‘/path/to/raw.json’

Query

```
SELECT “user.lang”,
       AVG(LENGTH(text))
  FROM tweets
 GROUP BY “user.lang”;
```

Pros and Cons

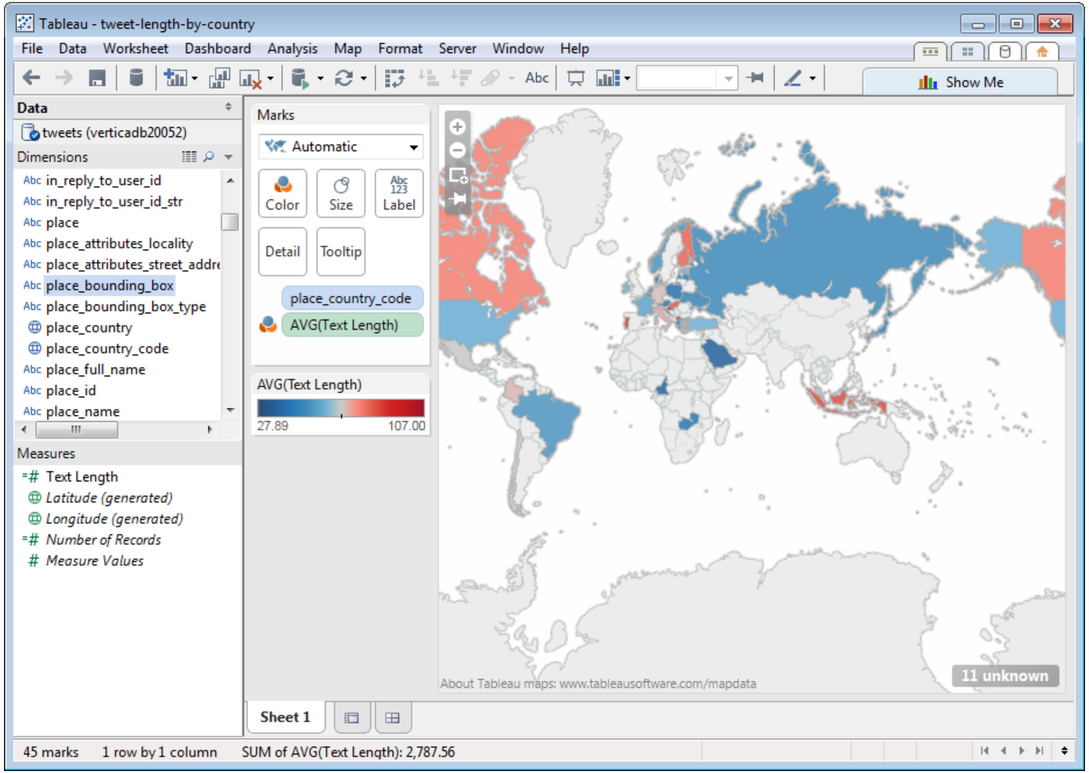
+ No schema definition

+ Simple to load

+ Easy to query

Tools Integration

"SQL makes a world of difference"



45 marks 1 row by 1 column SUM of AVG(Text Length): 2,787.56

Why Semi-Structured?

“Enabling ELT in addition to ETL”

- Just toss the data in (data lake)
  - Not worth putting the effort into discovering/defining schema when you’re not sure you’ll ever use the data
- Postpone the decision of which columns and types are “important” in the source data
- Allow for schema discovery while leveraging (a subset of) the benefits of the Vertica System rather than forcing it to be known at load-time
- Allow for incremental transform into the final, desired form while keeping the table usable
- Smooth out version/implementation differences in otherwise well-structured data
- Retain a SQL interface and its tools support, employee trainings, etc.

Implementation

“The devil’s in the details… and there are lots of details”

Components:

- **Supporting FLEX tables**
- **Performance optimization**
- **Validation of approach**

Objectives:

- **Simple to use**
- **Vanilla SQL**
- **Format agnostic storage**
- **Minimal added database complexity**

Flexible Tables

“I’d like my table *medium rare*”

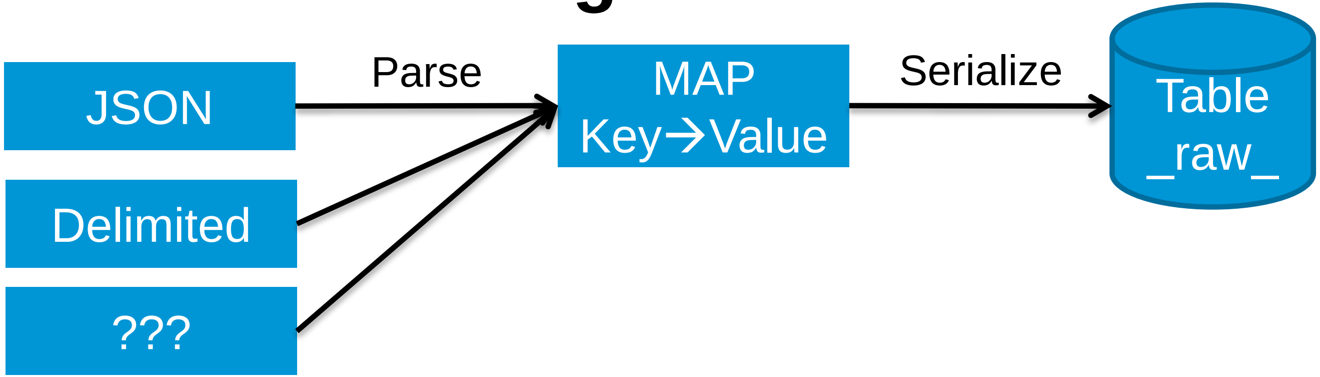
Store data in large binary column:

```
CREATE FLEX TABLE tweets();
```

is

```
CREATE TABLE tweets (
  __raw__ long varbinary
);
```

Flexible Tables: Parsing Semi-structured Data



JSON:

```
{
  “id”: 1,
  “name”: “ben”
}
```

Becomes a record:

{ “id” → “1”, “name” → “ben” }

Delimited with header row:

```
id,name
1,ben
2,jen
```

Becomes 2 records:

{ “id” → “1”, “name” → “ben” }

{ “id” → “2”, “name” → “jen” }

Extensible with User Defined Parsers

```
Avro, Protocol buffers,
Thrift, …
```

Fun Fact: Our JSON and Delimited parsers are actually user defined parsers

Flexible Tables: Supporting Vanilla SQL

“Column if you got ‘em!”

Automatic Query Rewrite

```
SELECT text FROM tweets;
```

becomes:

```
SELECT MapLookup(__raw__,’text’)
  FROM tweets;
```

Implementation

- **Vertica SQL-parser-level change**
- **Translates any column reference**
- **maplookup is null if key is missing**

Flexible Tables: SELECT * FROM tweets

“Wish upon a falling *”

- What it probably means:

Return all the data as a relational table

- Bad choices:
  - Return strings of JSON
    - Must track provenance (could be delimited, avro, …)
    - Useless to SQL tools
  - Return rows with all keys as columns
    - Requires full scan to compute columns
    - Could result in millions of columns
    - Loading data could invalidate consumer assumptions about schema

Flexible Tables: Column Metadata

"A view from the top"

Solution: build a view

- Compute set of available keys and strore in a keys table: compute_flextable_keys()
- Generate view from keys: build_flextable_view() / compute_flextable_keys_and_build_view()
- SQL Tools understand views
- Regenerate keys & view to expose new schema to applications
- Can still access base flex table

Example:

Table people has rows:

{ name → ben, hair → blond }

{ name → jen, eyes → green }

```
SELECT * FROM people_view:
name | hair  | eyes
Ben  | blond |
Jen  |       | green
```

Handling Nested Structure: Exploding

Give me the text of all posts tagged “big data”

```
SELECT text
    FROM posts
    WHERE 'big data' IN tags;


SELECT * FROM (SELECT
    text, MapItems(tags)
    OVER(PARTITION BY text, tags)
    FROM posts) innerPosts
  WHERE values = 'big data';
```

```
                  text                       | keys |  values
---------------------------------------------+------+----------
 Giving a talk on Flexible Tables at Brandeis. | 3    | big data
(1 row)
```

```
{
   "postID": 52737,
   "posterID": 134028,
   "text": "Giving a talk on
Flexible Tables at Brandeis.",

   "tags":
     ["flex", "vertica", "hp", "big
data"],

   "replyPostsIDs":
     [52740, 52756, 52757, 52810]
}
```

Handling Nested Structure (Maps & Lists)

“… may none of them be missed!”

Maps get flattened

```
{
  “a”: 5,
  “b”: {
         “c”: 4,
         “d”: 7
       }
}
```

becomes

{ a → 5, “b.c” → 4, “b.d” → 7 }

Lists become sub-maps

```
{
  “a”: [ “red”, “green”]
}
```

becomes

{ a → { 0 → “red”, 1 → “green” } }

Performance

- Likely in the “Big Data” arena – performance at scale matters
- Load is wonderfully parallel – each record is self-contained
- Query performance:
  - Structure hidden inside __raw__ column
  - SQL does not distinguish between **real** columns and **virtual** columns
  - A column-store database is crucial

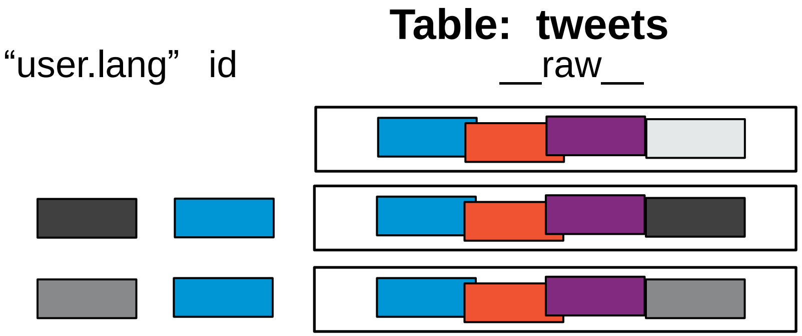
Performance: Column-Store Basics

“My precious… Column! Column!”

- Store each column’s data separately, often sorted and compressed
- Benefits:
  - Pay I/O cost only for columns referenced
  - Late materialize columns after predicates or even joins
  - Easy to add columns to a table

Performance: Flex → Relational

“Optimization via PowerPoint”



```
CREATE TABLE tweets (
  __raw__ long varbinary,
  “user.lang” varchar(10),
  id int
)
ORDER BY “user.lang”;
```

Push-Button Process:

1. **Column Materialization**
   DB tracks used columns
2. **Database Designer**
   Optimizes physical layout

Performance: Hybrid Flex Tables

“Best of both worlds”

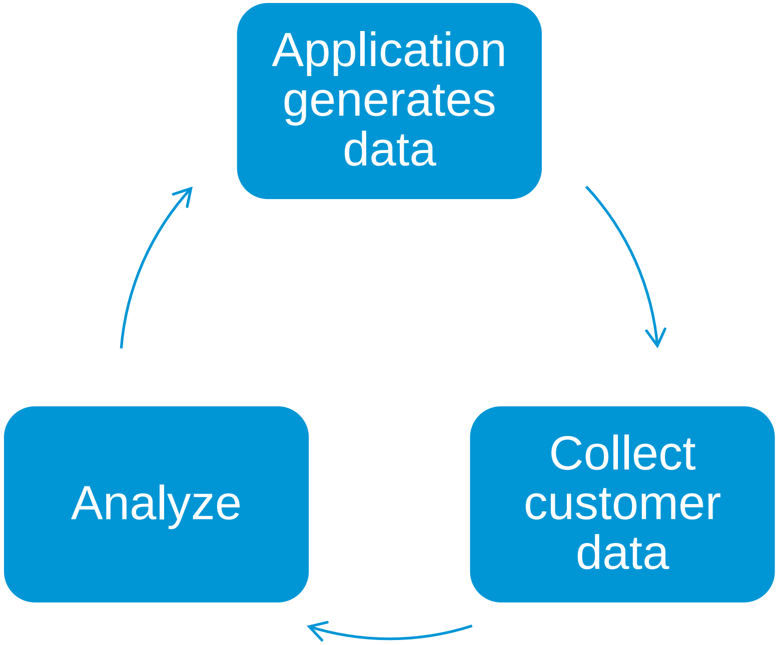
- Supports partial description
  - Some parts of data fixed & known
  - Improved performance
- Re-uses performance mechanisms
- SQL Query is identical

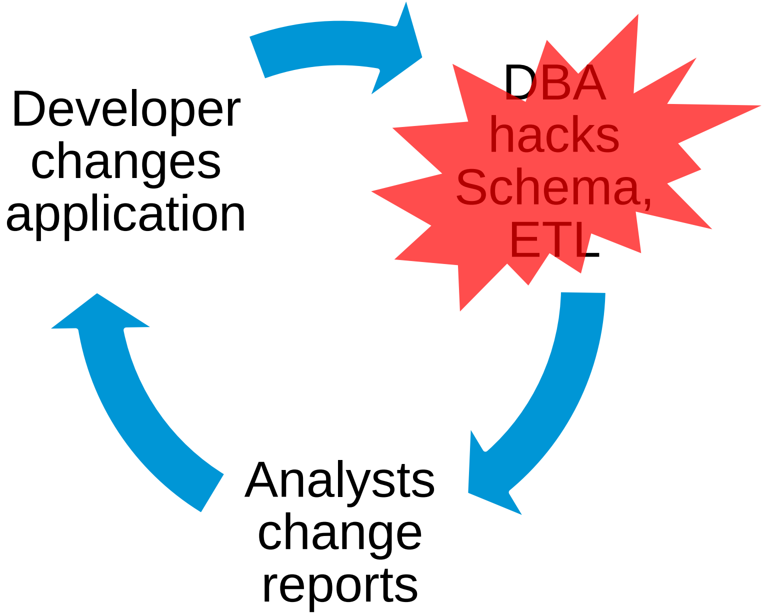
Partial Description

```
CREATE FLEX TABLE tweets(
  time timestamp,
  id int,
  “user.lang” varchar(20)
)
ORDER BY “user.lang”,time
SEGMENTED BY hash(id) ALL NODES;
```

Validation: Customers

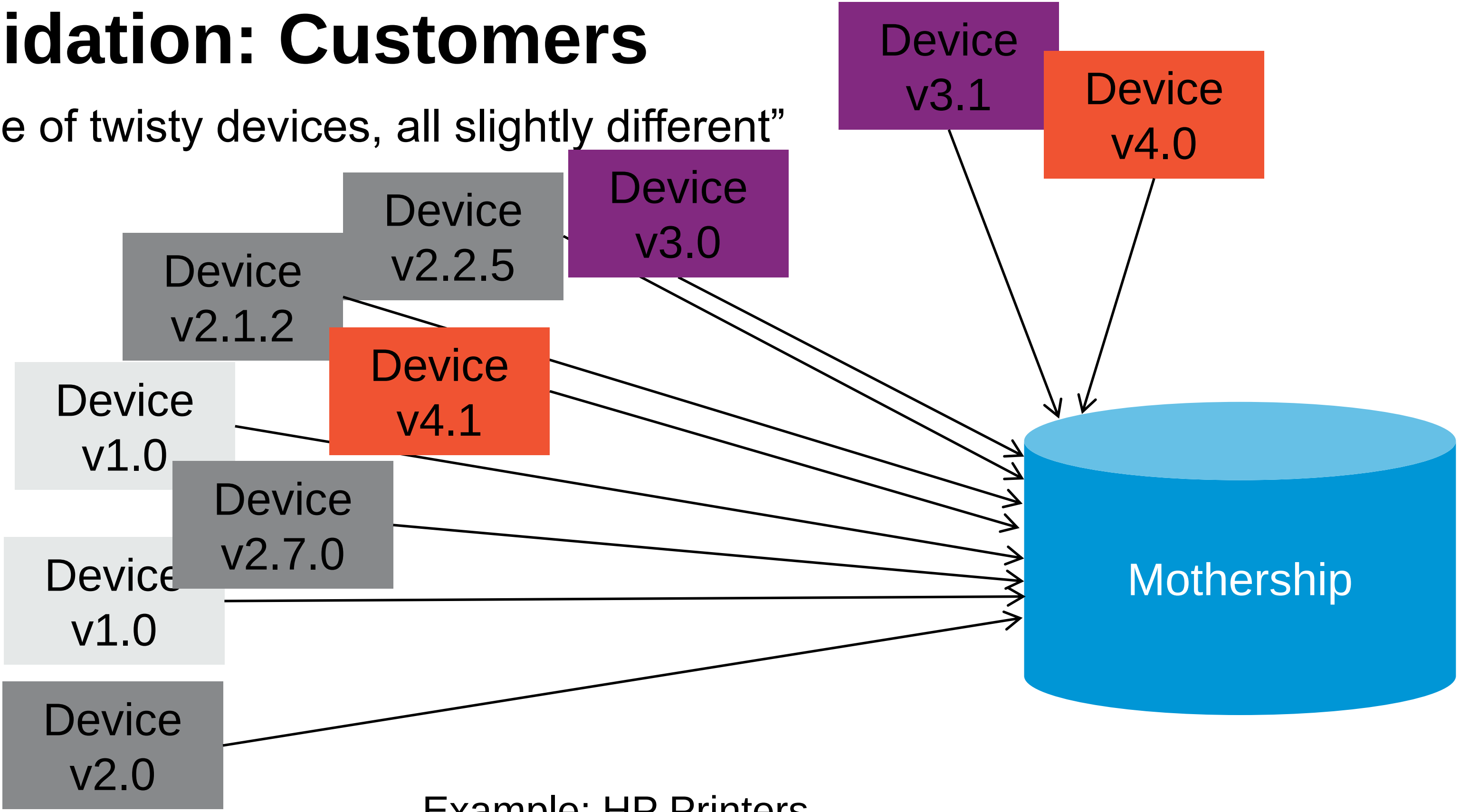
"Finding pain points"





Validation: Customers

“Maze of twisty devices, all slightly different”



Example: HP Printers

Schema evolves, cannot change installed devices

Validation: Results

“Dogfooding”

Usability

Case study: Vertica internal log tables

- Standard base columns (time,txnid,…)
- Variety of payload columns
- Columns vary between versions
- Stored in delimited format with headers

Requirement

Simple load process which works regardless of Vertica version

Example: dc_transaction_ends table

```
            time              |   transaction_id   | is_ddl | rows_written
------------------------------+-------------------+--------+-------------
 2013-07-20 15:51:29.065174-04 | 45035996275768002 | f      |            0
 2013-07-20 15:51:29.119749-04 | 45035996275768020 | t      |            0
 2013-07-20 15:51:29.182637-04 | 45035996275768021 | t      |            0
 2013-07-20 15:51:39.811272-04 | 45035996275768024 | f      |            0
 2013-07-20 15:51:51.213977-04 | 45035996275768025 | f      |            0
 2013-07-20 15:51:51.221161-04 | 45035996275768026 | t      |            0
 2013-07-20 15:51:52.984709-04 | 45035996275768027 | t      |            0
 2013-07-20 15:51:52.995551-04 | 45035996275768028 | t      |            0
 2013-07-20 15:51:54.7341-04   | 45035996275768029 | f      |           94
 2013-07-20 15:52:29.468858-04 | 45035996275768032 | t      |            0
```

Validation: Results

“Hybrid table FTW!”

Usage

For each log file:

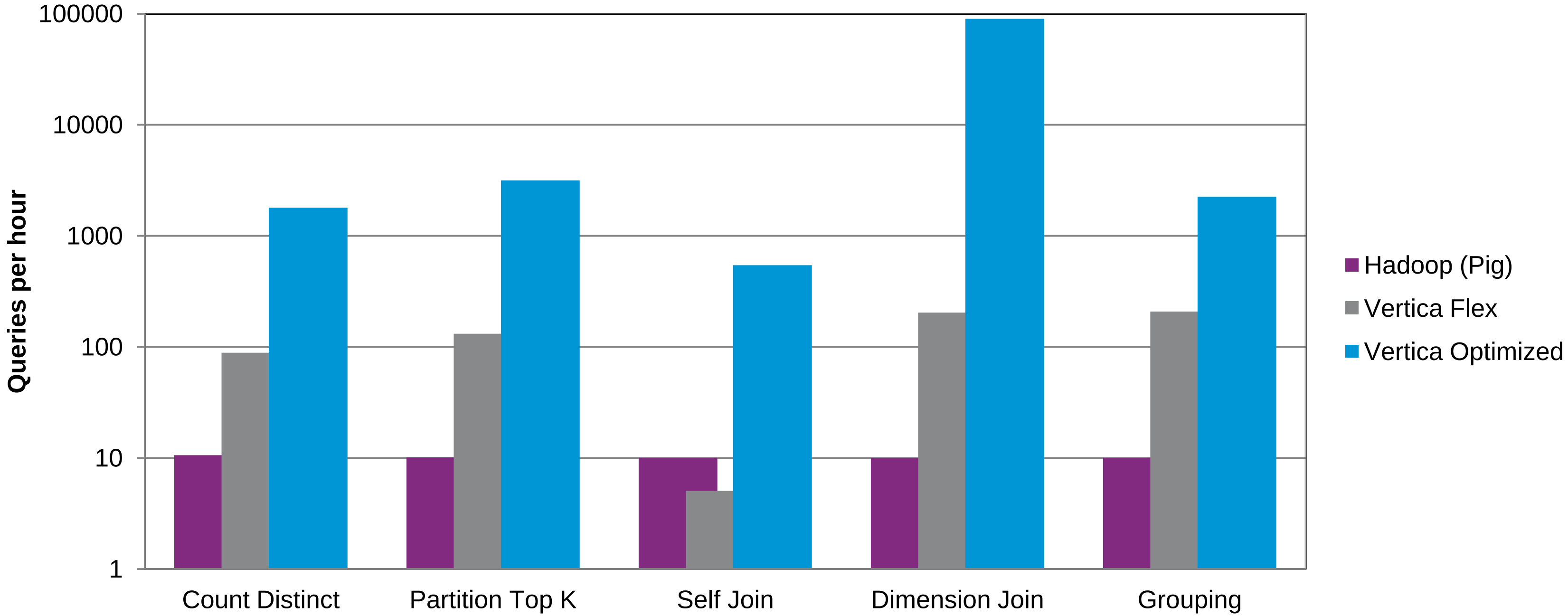
- Create hybrid flex table
- Load file into table

No need for performance optimization:
Important columns already exist

```
CREATE FLEX TABLE dc_table (
    time timestamp,
    node_name varchar(100),
    session_id varchar(100),
    transaction_id int,
    statement_id int
 )
ORDER BY
transaction_id,statement_id,node_name,time
SEGMENTED BY
hash(transaction_id,statement_id) ALL NODES;
```

Validation: Performance of Vertica Flex vs Pig

“I’ll huff and I’ll puff…”



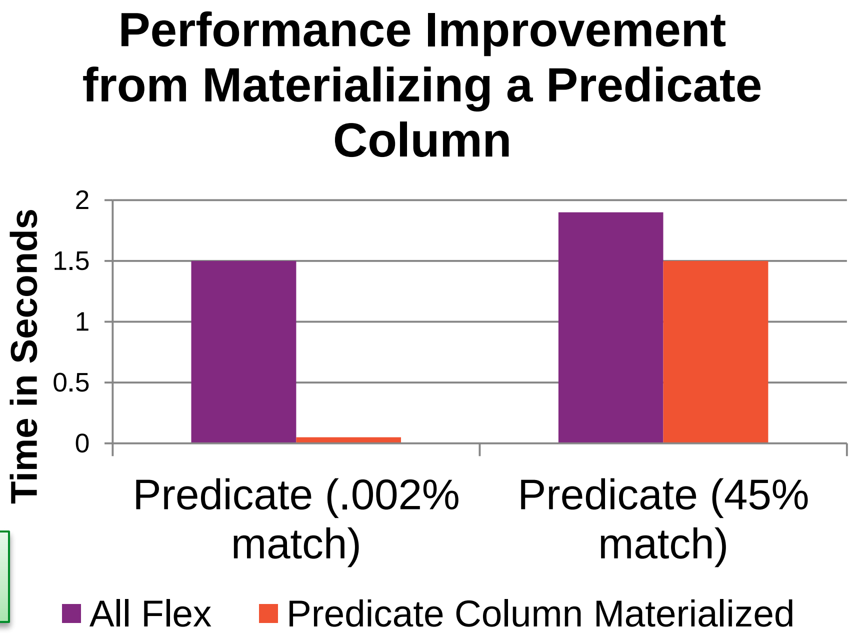
Tweets: 100 hrs of samples, 38GB raw, 17 million rows – **Cluster**: 4 Nodes, 100GB RAM, 8 cores

Validation: Effectiveness of Hybrid Tables

SELECT text FROM tweets
WHERE “user.lang” = ______

- All flex:
  - scan all rows
- Materialize “user.lang”:
  - scan “user.lang” first
  - scan __raw__ for matching

Cost to Store Column: 194 bytes!


Performance Improvement from Materializing a Predicate Column

Conclusions

“What next?”

Current State

- **Support load, exploration, and productization of semi-structured data**
- **Provides vanilla SQL experience key to ecosystem integration**
- **Push button performance optimization with orders of magnitude impact**
- **Shipped in Vertica 7.0 (Dec 2013)**

Future Work

- **Support additional formats**
- **Better algorithms**
  - View Generation
  - Column Materialization
- **Performance tuning**
  - Storage compression
  - SQL Optimizer statistics

We’re hiring!

In case you hadn’t guessed.

Full-time and internship positions available!

We want intelligent, creative developers who aren’t afraid to learn new stuff.

- Everything you just saw came out of some engineer’s head.
- Are you someone like that? Want to work with people like that?

We’ll help you find the right place at Vertica.

- Interview with (and get to know) your teammates
- We want people who know they want us

http://www.vertica.com/about/careers/ | http://www.vertica.com/blog/ | http://my.vertica.com/ | https://vertica.hpwsportal.com/ | resumes@vertica.com

Artwork courtesy of openclipart.org

Thank you! Questions?

Try it yourself with Vertica Community Edition:
http://www.vertica.com/community
Full featured; first 2 terabytes are free!
(1TB Flex, 1TB columnar)

Flex QuickStart Guide at:
http://my.vertica.com/docs/7.0.x/PDF/HP_Vertica_7.0.x_FlextablesQuickstart.pdf

Thanks to the whole Flex Crew:

Ben Vandiver, Shalu Tiwari, Kanti Mann,

Tina Hsu, Adam Seering, Derrick Rice,
Jason Slaunwhite, Sue Francis,

Lyric Doshi, Matt Fuller

Map Functions

Scalar Functions

- MapLookup(map,key) → value
  or *null* if map does not contain key
- MapContainsKey(map,key) → boolean
- MapSize(map) → integer

Transform Functions (multi-row output)

- MapKeys(map) → keys, one per row
- MapValues(map) → values, one per row

Aggregate Functions

- MapAggregate(keys,values) → map

…

Maps can stand in for arrays: use keys 0,1,2,…

Examples:

View the contents of a Flex map:

SELECT MapToString(__raw__) FROM tweets;

Find all unique keys in a map column:

SELECT DINSTINCT key FROM

(SELECT MapKeys(__raw__) OVER() FROM tweets) a;

Handling Nested Structure: Exploding

How do I query nested objects?

```
SELECT MapItems(tags)
    OVER(PARTITION AUTO)
    FROM posts;
```

```
 keys |  values
------+----------
 0    | flex
 1    | vertica
 2    | hp
 3    | big data
(4 rows)
```

```
SELECT text, MapItems(tags)
    OVER(PARTITION BY text, tags)
    FROM posts;
```

```
                    text                    | keys |  values
--------------------------------------------+------+----------
 Giving a talk on Flexible Tables at Brandeis. | 0    | flex
 Giving a talk on Flexible Tables at Brandeis. | 1    | vertica
 Giving a talk on Flexible Tables at Brandeis. | 2    | hp
 Giving a talk on Flexible Tables at Brandeis. | 3    | big data
(4 rows)
```

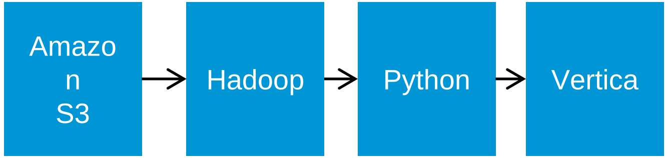
```
{
  "postID": 52737,
  "posterID": 134028,
  "text": "Giving a talk on
Flexible Tables at Brandeis.",

  "tags":
    ["flex", "vertica", "hp", "big
data"],

  "replyPostsIDs":
    [52740, 52756, 52757, 52810]
}
```

Customer Stories

“Of woe and tears”

Gaming Company Scenario

- Event data from games
- Load process:



Amazo n S3 → Hadoop → Python → Vertica

- Repeat for every event type
- Events change: make new tables (tbl1 → tbl2)
- Want to co-locate all events for a game
- All events have 8 known fields

Not just gaming:

- **Advertising**
- **Medical**
- **Web analytics**
- **…**

Common Elements

Customer defines data to be collected

Customer loads & analyzes data in Vertica

Adjusts collection over time

Related Work

- Many customers do ETL to work around
- Postgres, Oracle, and other support JSON – but not in SQL
- Clustrix gets close, but keys don’t look like columns
  http://sergei.clustrix.com/2011/02/clustrix-as-document-store-blending-sql.html
- XML databases – xpath queries aren’t SQL