EPL646 – Advanced Topics in Databases

Lecture 13

NoSQL Databases: CouchDB II
(Semi-structured JSON DB)

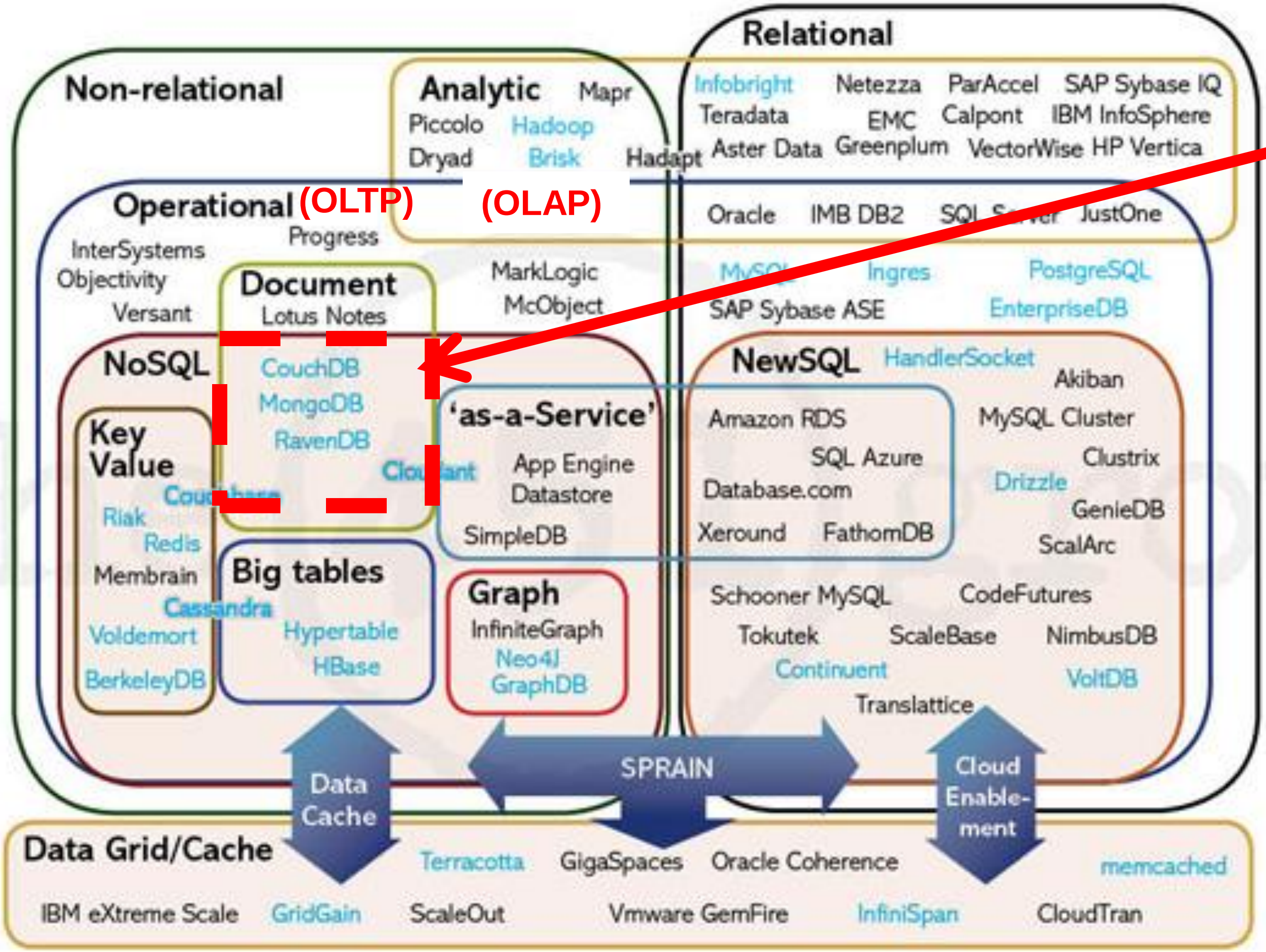
Chapter 20: Abiteboul et. Al.

+ http://guide.couchdb.org/

Demetris Zeinalipour

http://www.cs.ucy.ac.cy/~dzeina/courses/epl646

EPL646: Part B
Distributed/Web/Cloud DBs/Dstores



(OLTP)

(OLAP)

Lecture Focus

Venn Diagram by 451 group

http://xeround.com/blog/2011/04/newsql-cloud-database-as-a-service

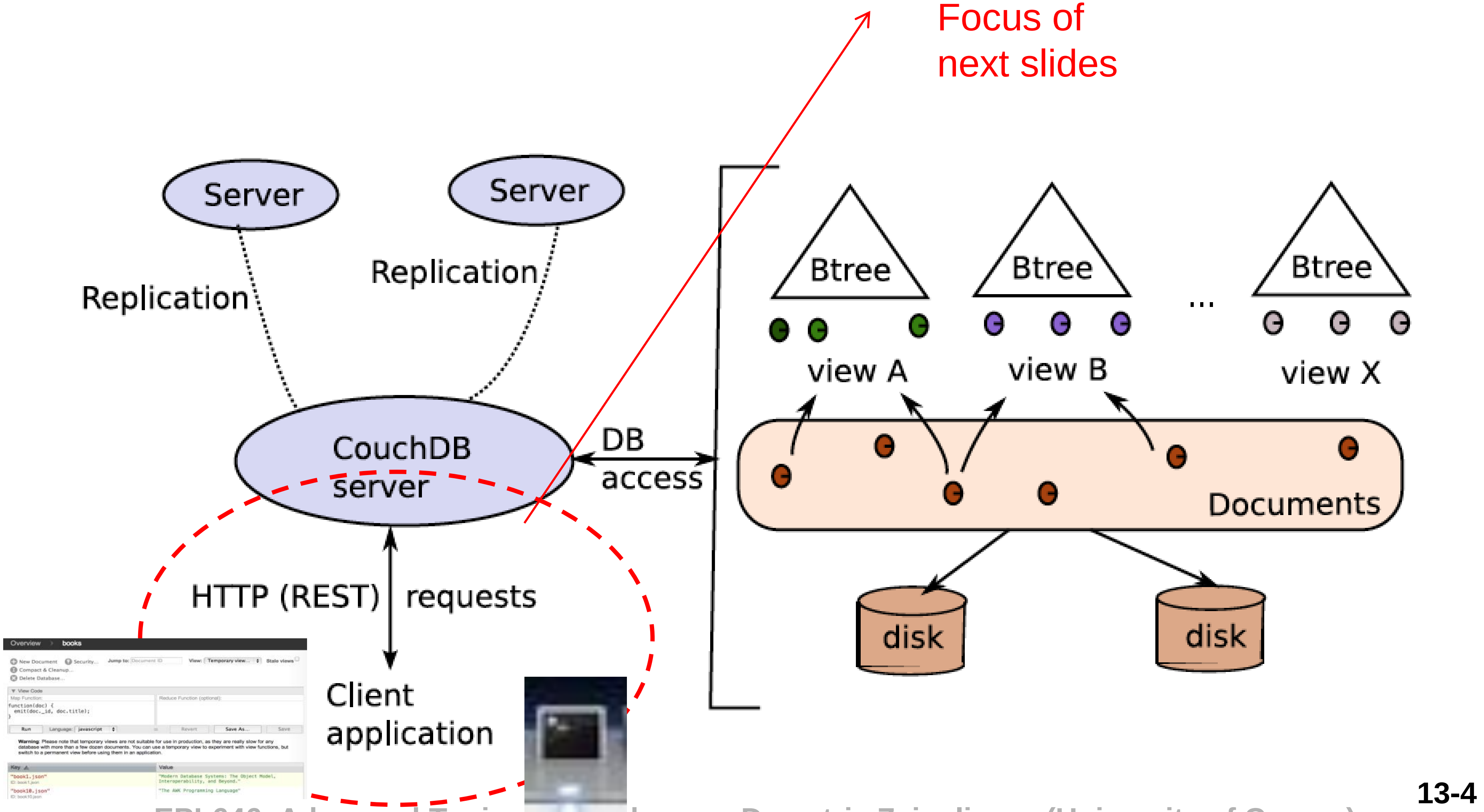
Lecture Outline
(Introduction to Semi-structured Data)

- Intro to Web2.0 & JSON Data Interchange Format
- JSON Key-Value Data Model
- CouchDB: A JSON Database (written in Erlang)
  - Using Command Line CURL/ Web-based FUTON
  - CouchDB Architecture (Btrees, Filesystem, Replication)
  - REST Principles
  - Creating DBs, Adding Docs, Updating Docs, Deleting Docs, _ID and _REV issues, Multi-Version CC (MVCC)
  - Querying Data with (Materialized) Views (Map-Reduce style in Javascript)
  - Replication and Scalability Issues

CouchDB REST Interface

Architecture of CouchDB

Focus of next slides



Overview › books

New Document · Security... · Compact & Cleanup... · Delete Database...

Jump to: Document ID · View: Temporary view... · Stale views □

▼ View Code

Map Function:

```
function(doc) {
  emit(doc._id, doc.title);
}
```

Reduce Function (optional):

Run · Language: javascript · Revert · Save As... · Save

Warning: Please note that temporary views are not suitable for use in production, as they are really slow for any database with more than a few dozen documents. You can use a temporary view to experiment with view functions, but switch to a permanent view before using them in an application.

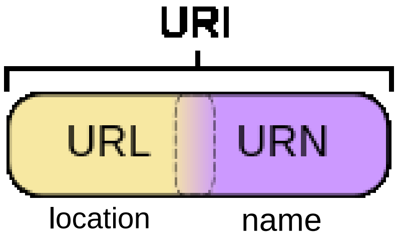
Key	Value
"book1.json" ID: book1.json	"Modern Database Systems: The Object Model, Interoperability, and Beyond."
"book10.json" ID: book10.json	"The AWK Programming Language"

REST Principles

ApartÃ©: REST principles

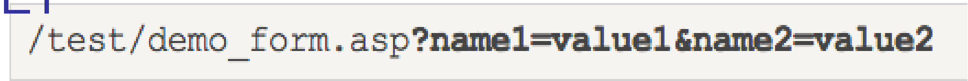
Roy Fielding (Univ. of Calif, Irvine PhD)
Founder of Apache HTTP Project
HTTP 1.0 (RFC1945) w/ Berners-Lee
HTTP 1.1 (RFC2616) w/ others

A Web-service dialect that enables exchanges of HTTP messages to access, create, and manage resources.
protocol as follows:



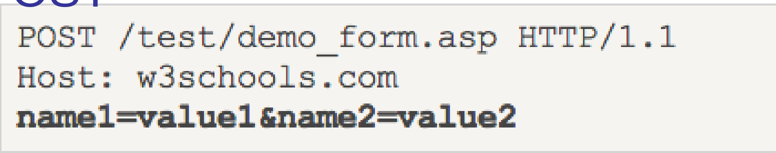
- **GET** retrieves the resource referenced by the URI.
- **PUT** creates the resource at the given URI.
- **POST** sends a message (along with some data) to an existing resource.
- **DELETE** deletes the resource.

GET



```
/test/demo_form.asp?name1=value1&name2=value2
```

POST

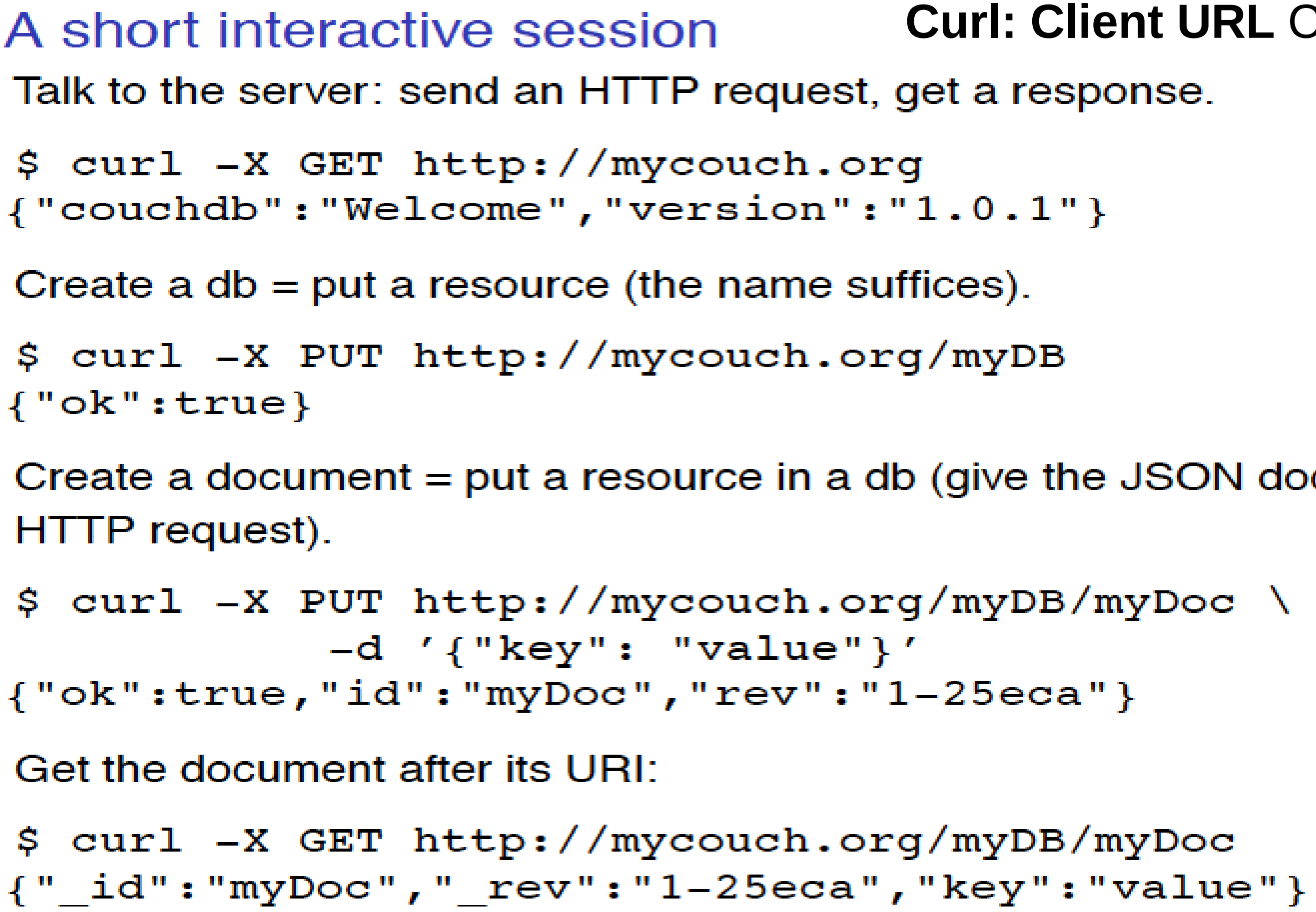


```
POST /test/demo_form.asp HTTP/1.1
Host: w3schools.com
name1=value1&name2=value2
```

Very convenient in a Web environment: no need to use a client library – Documents can easily be incorporated in a Web interface.

CouchDB: CREATE DB / INSERT (with CURL)

Curl: Client URL Command Line Tool



A short interactive session

Talk to the server: send an HTTP request, get a response.

```
$ curl -X GET http://mycouch.org
{"couchdb":"Welcome","version":"1.0.1"}
```

Create a db = put a resource (the name suffices).

```
$ curl -X PUT http://mycouch.org/myDB
{"ok":true}
```

Create a document = put a resource in a db (give the JSON document in the HTTP request).

```
$ curl -X PUT http://mycouch.org/myDB/myDoc \
           -d '{"key": "value"}'
{"ok":true,"id":"myDoc","rev":"1-25eca"}
```

Get the document after its URI:

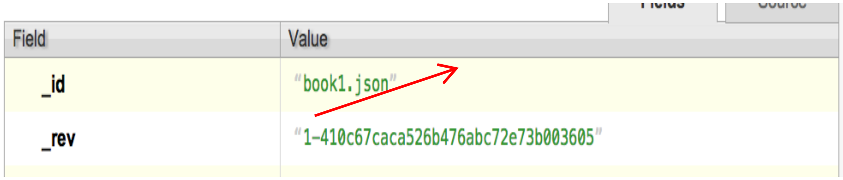
```
$ curl -X GET http://mycouch.org/myDB/myDoc
{"_id":"myDoc","_rev":"1-25eca","key":"value"}
```

Retrieve all tables (e.g., show tables; in MySQL)

```
$ curl -X GET http://127.0.0.1:5984/_all_dbs
["_replicator","_users","books","booksreplica","movies","twitter"]
```

CouchDB: _ID and _REV

Document management in CouchDB



Field	Value
_id	"book1.json"
_rev	"1-410c67caca526b476abc72e73b003605"

Each document has an id and a revision number.

Use: `uuidgen` to generate uniq ids during insert

UUID=128bit (32Hex digits) = 2.4x10^38 keys

Each update to a document creates an new version, with the same `_id` but a new revision number.

Validation functions can be assigned to a collection: any document inserted or updated must be validated by these functions (ad-hoc type-checking). *Like triggers…*

Design documents are a special type of CouchDB document that contains application code.

A view is a new key-document collection, specified via MAPREDUCE.

(we will see views later)

Documents can be replicated in other CouchDB instances.

(we will see replication later)

CouchDB: BULK LOAD (with CURL)

```
# Download the files from the web
#(or wget http://webdam.inria.fr/Jorge/files/jsonmovies.zip)
$ curl -O http://webdam.inria.fr/Jorge/files/jsonmovies.zip

# Unzip Movies
$ unzip jsonmovies.zip

# List the files
$ ls -al | head
total 12480
-rw-r--r--@    1 dzeina  staff    218  9 ??t  2011 book1.json
-rw-r--r--@    1 dzeina  staff    222  9 ??t  2011 book10.json
-rw-r--r--@    1 dzeina  staff    197  9 ??t  2011 book100.json

# Bulk load using Bash
$ for i in `ls .`; do curl -X PUT $COUCHDB/movies/$i -d \@$i; done
{"ok":true,"id":"book1.json","rev":"1-410c67caca526b476abc72e73b003605"}
{"ok":true,"id":"book10.json","rev":"1-d0cc2ae0ab3211314a65a5c5244df221"}
{"ok":true,"id":"book100.json","rev":"1-2cfe83eea8cad920cfd66755ac78b46f"}
```

```
# or assign unique IDs
$COUCHDB/movies/`uuidgen`
```

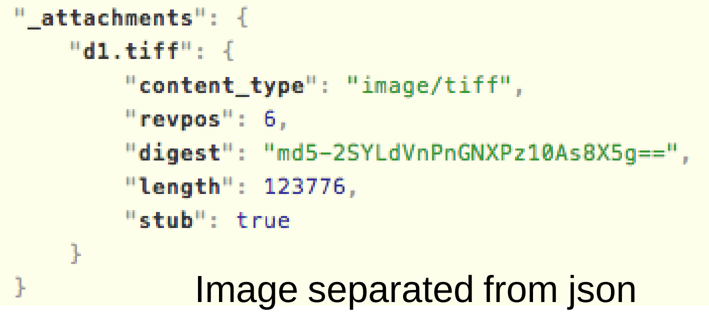
CouchDB: UPDATE / DELETE (with CURL)

Updating data

Updating in CouchDB = adding a new version.

CouchDB applies a Multi-version concurrency control protocol which requires that you send the version that must be updated:

```
$ curl -X PUT $IP/movies/tsn?rev=1-db1261 -d @newDoc.json \
   -H "Content-Type: image/jpg"
{"ok":true,"id":"tsn","rev":"2-26863"}
```



```
"_attachments": {
    "d1.tiff": {
        "content_type": "image/tiff",
        "revpos": 6,
        "digest": "md5-2SYLdVnPnGNXPz10As8X5g==",
        "length": 123776,
        "stub": true
    }
}
```

Image separated from json

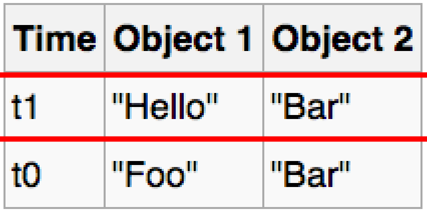
Deletion is obtained with `DELETE`.

```
$ curl -X DELETE $COUCHADDRESS/movies/tsn?rev=2-26863
{"ok":true,"id":"tsn","rev":"3-48e92b"}
```

A new version has been created! (logical deletion).

CouchDB: UPDATE / DELETE (MVCC Explained)

- **Multi-Version CC (MVCC)** uses timestamps or increasing IDs to achieve transactional consistency.
  - MVCC provides each user with a snapshot of the database
- The database holds multiple versions (e.g., t0, t1 for Obj1)

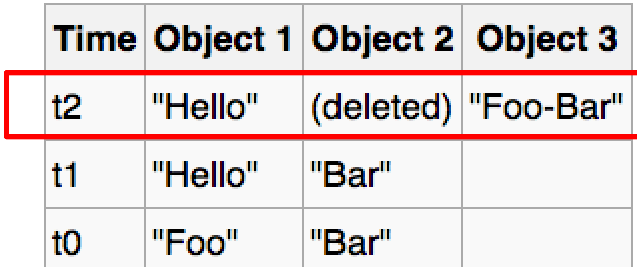


Time	Object 1	Object 2
t1	"Hello"	"Bar"
t0	"Foo"	"Bar"

Latest Version

- Assume that a **T1** is a long-running READ xact started with state **"t1"**
- Also assume that **T2** is a WRITE transaction that creates state **"t2"**

T1 continues to have access to the t1 state! (thus, the necessary ISOLATION)



Time	Object 1	Object 2	Object 3
t2	"Hello"	(deleted)	"Foo-Bar"
t1	"Hello"	"Bar"	
t0	"Foo"	"Bar"	

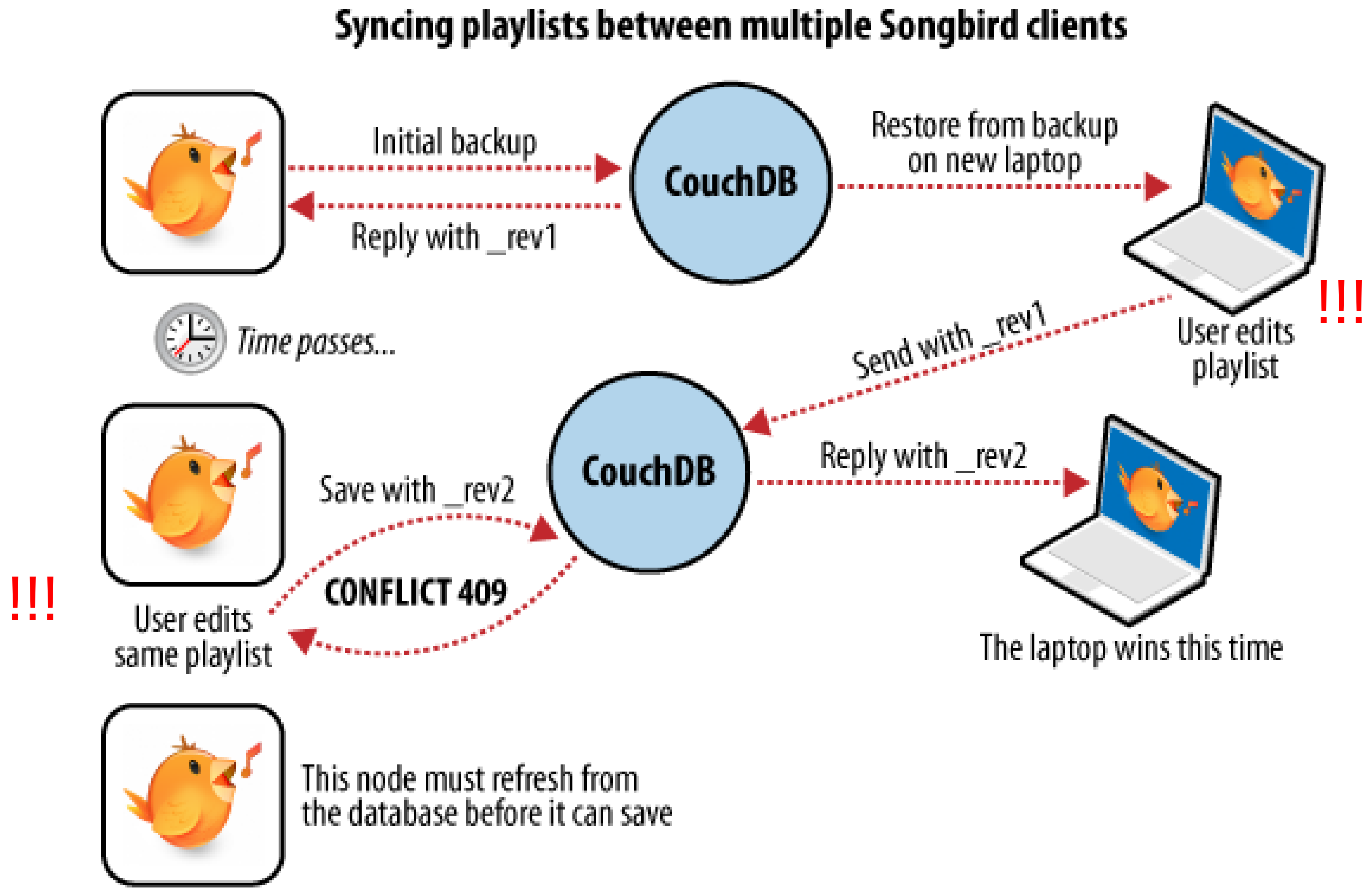
Latest Version

For **serializability / recoverability:** Multiversion Histories need to follow similar ideas to Single-version Histories we saw with Basic TO and Strict TO.

CouchDB: UPDATE / DELETE (with CURL)

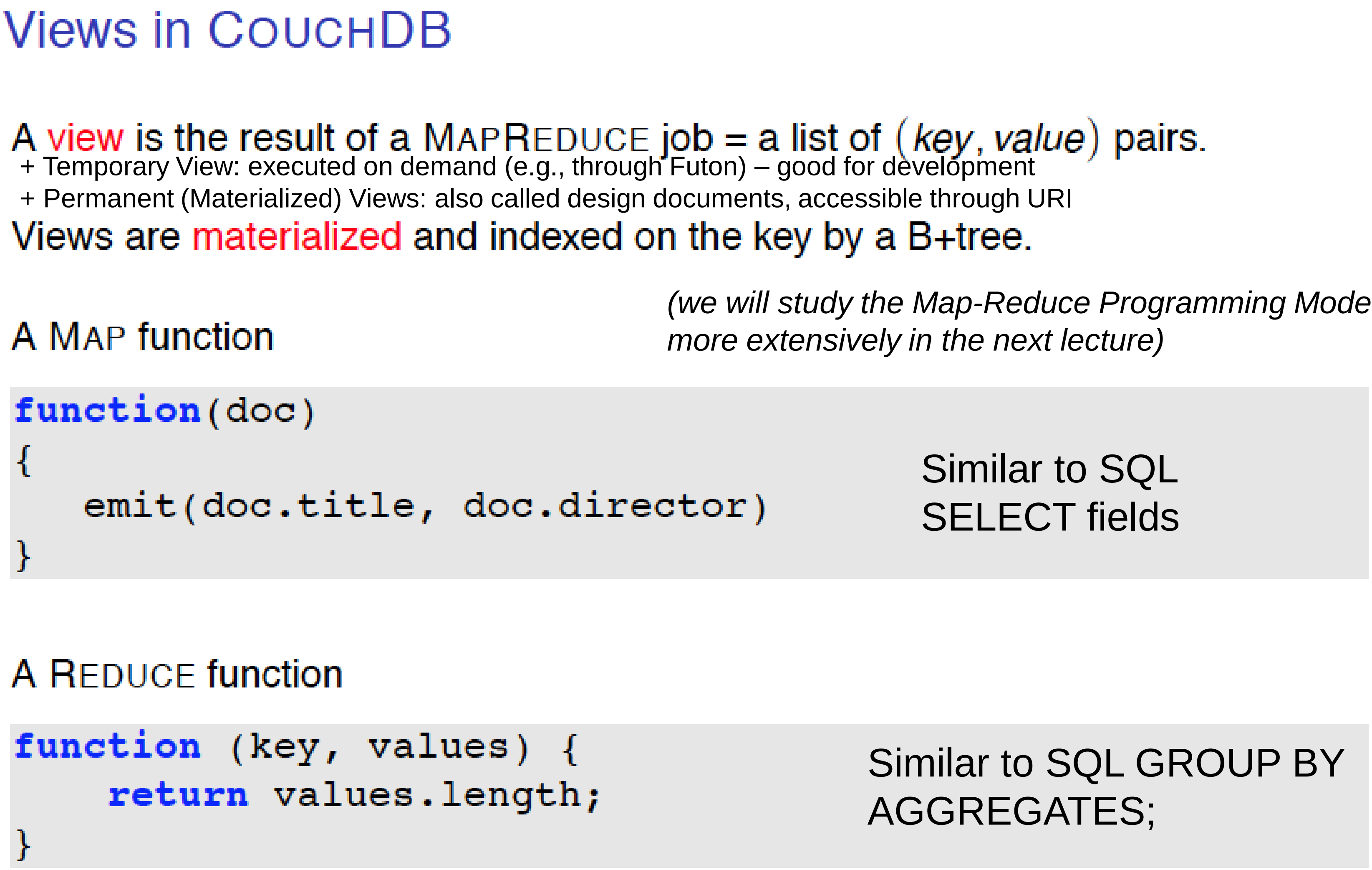
```
# UPDATE document "4C4F2E4C-E1AC-4C80-B90E-A9D0BCB638C8"
$ curl -X PUT $COUCHDB/googlebooks/4C4F2E4C-E1AC-4C80-B90E-
  A9D0BCB638C8?rev=1-1d974c2aadd42b0b8699678d61a0e4ff -d
  @potter.json
{"ok":true,"id":"4C4F2E4C-E1AC-4C80-B90E-
  A9D0BCB638C8","rev":"2-40d4b6bf3530e6af3a84904652ce9a8c"}

# Now DELETE PRELAST version "rev=1-
  1d974c2aadd42b0b8699678d61a0e4ff"
$ curl -X DELETE $COUCHDB/googlebooks/4C4F2E4C-E1AC-4C80-B90E-
  A9D0BCB638C8?rev=1-1d974c2aadd42b0b8699678d61a0e4ff
{"error":"conflict","reason":"Document update conflict."}

# DELETE LAST version "rev=2-40d4b6bf3530e6af3a84904652ce9a8c"
$ curl -X DELETE $COUCHDB/googlebooks/4C4F2E4C-E1AC-4C80-B90E-
  A9D0BCB638C8?rev=2-40d4b6bf3530e6af3a84904652ce9a8c
{"ok":true,"id":"4C4F2E4C-E1AC-4C80-B90E-
  A9D0BCB638C8","rev":"3-a77d6120602b51cbf9b8663c1ee8f9e3"}
```

CouchDB: UPDATE / DELETE (Example)



Syncing playlists between multiple Songbird clients
Initial backup
Reply with _rev1
CouchDB
Restore from backup on new laptop
Time passes...
Send with _rev1
User edits playlist
!!!
CouchDB
Reply with _rev2
Save with _rev2
CONFLICT 409
!!!
User edits same playlist
The laptop wins this time
This node must refresh from the database before it can save

CouchDB: SELECT QUERY (expressed as Javascript)



Views in CouchDB

A view is the result of a MapReduce job = a list of (*key*, *value*) pairs.

+ Temporary View: executed on demand (e.g., through Futon) – good for development

+ Permanent (Materialized) Views: also called design documents, accessible through URI

Views are materialized and indexed on the key by a B+tree.

A Map function

(we will study the Map-Reduce Programming Model more extensively in the next lecture)

```
function(doc)
{
   emit(doc.title, doc.director)
}
```

Similar to SQL SELECT fields

A Reduce function

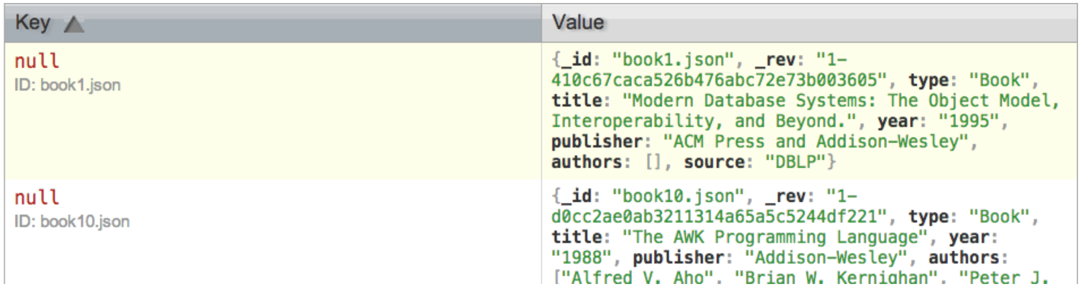
```
function (key, values) {
    return values.length;
}
```

Similar to SQL GROUP BY AGGREGATES;

Lecture Outline
(Introduction to Semi-structured Data)

- **SQL: SELECT * FROM Books;**

```
function(doc) {
    emit(null, doc);
}
```

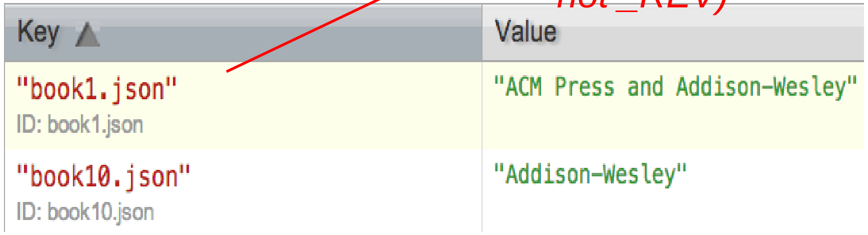


Key	Value
null ID: book1.json	{**_id**: "book1.json", **_rev**: "1-410c67caca526b476abc72e73b003605", **type**: "Book", **title**: "Modern Database Systems: The Object Model, Interoperability, and Beyond.", **year**: "1995", **publisher**: "ACM Press and Addison-Wesley", **authors**: [], **source**: "DBLP"}
null ID: book10.json	{**_id**: "book10.json", **_rev**: "1-d0cc2ae0ab3211314a65a5c5244df221", **type**: "Book", **title**: "The AWK Programming Language", **year**: "1988", **publisher**: "Addison-Wesley", **authors**: ["Alfred V. Aho", "Brian W. Kernighan", "Peter J.

- **SQL: SELECT pub FROM Books;**

_ID always part of answer (but not _REV)

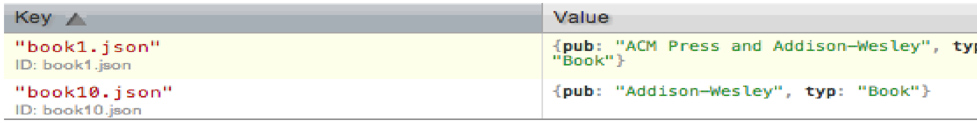
```
function(doc) {
    emit(doc._id, doc.publisher);
}
```



Key	Value
"book1.json" ID: book1.json	"ACM Press and Addison-Wesley"
"book10.json" ID: book10.json	"Addison-Wesley"

- **SQL: SELECT pub, typ FROM Books**

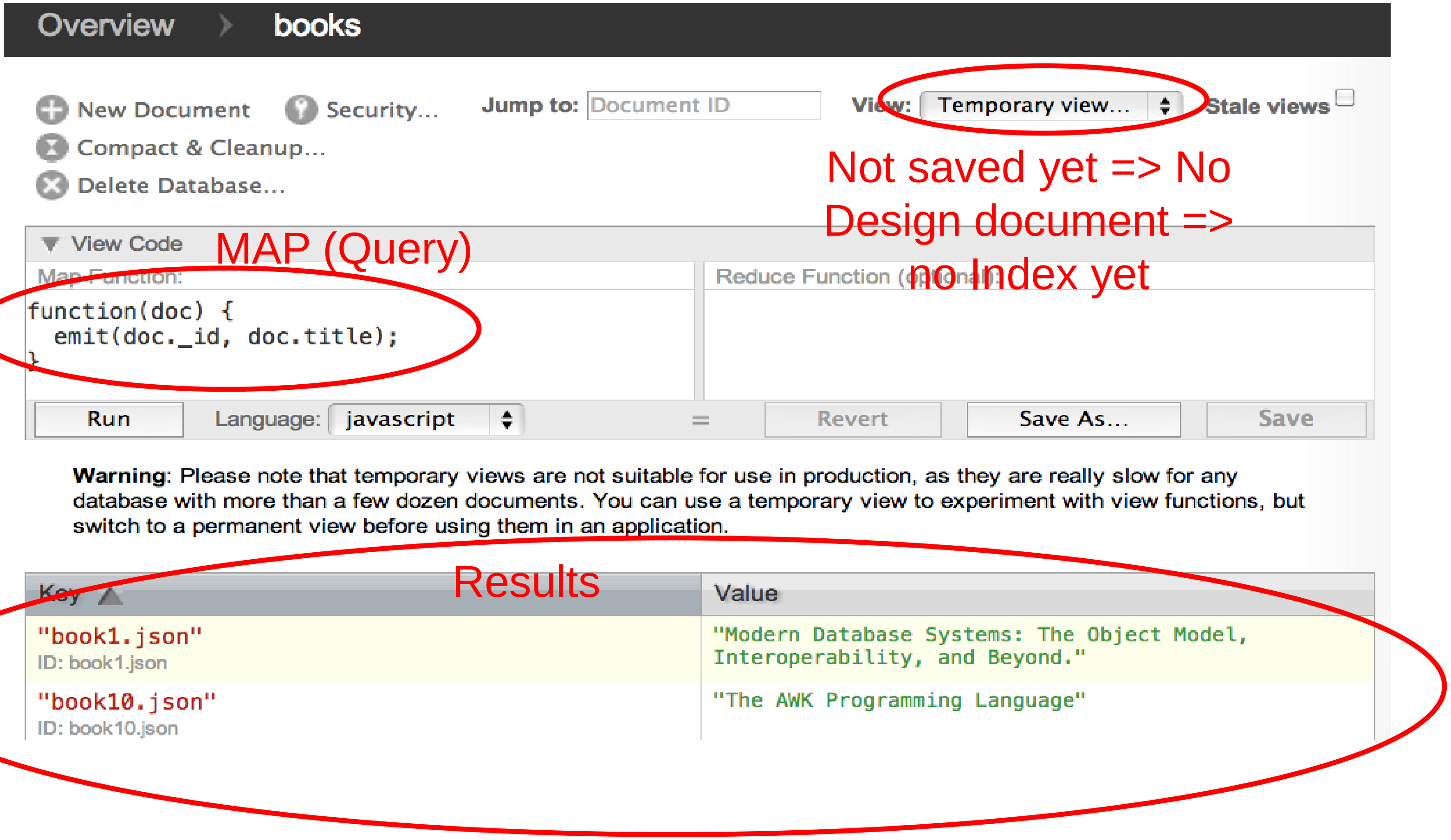
```
function(doc) {
    emit(doc._id,
         {"pub": doc.publisher, "typ": doc.type});
}
```



Key	Value
"book1.json" ID: book1.json	{**pub**: "ACM Press and Addison-Wesley", **typ**: "Book"}
"book10.json" ID: book10.json	{**pub**: "Addison-Wesley", **typ**: "Book"}

CouchDB: SELECT QUERY (with FUTON)

SQL Equivalent: SELECT B.title FROM Books B;



Not saved yet => No Design document => no Index yet

MAP (Query)

```
function(doc) {
  emit(doc._id, doc.title);
}
```

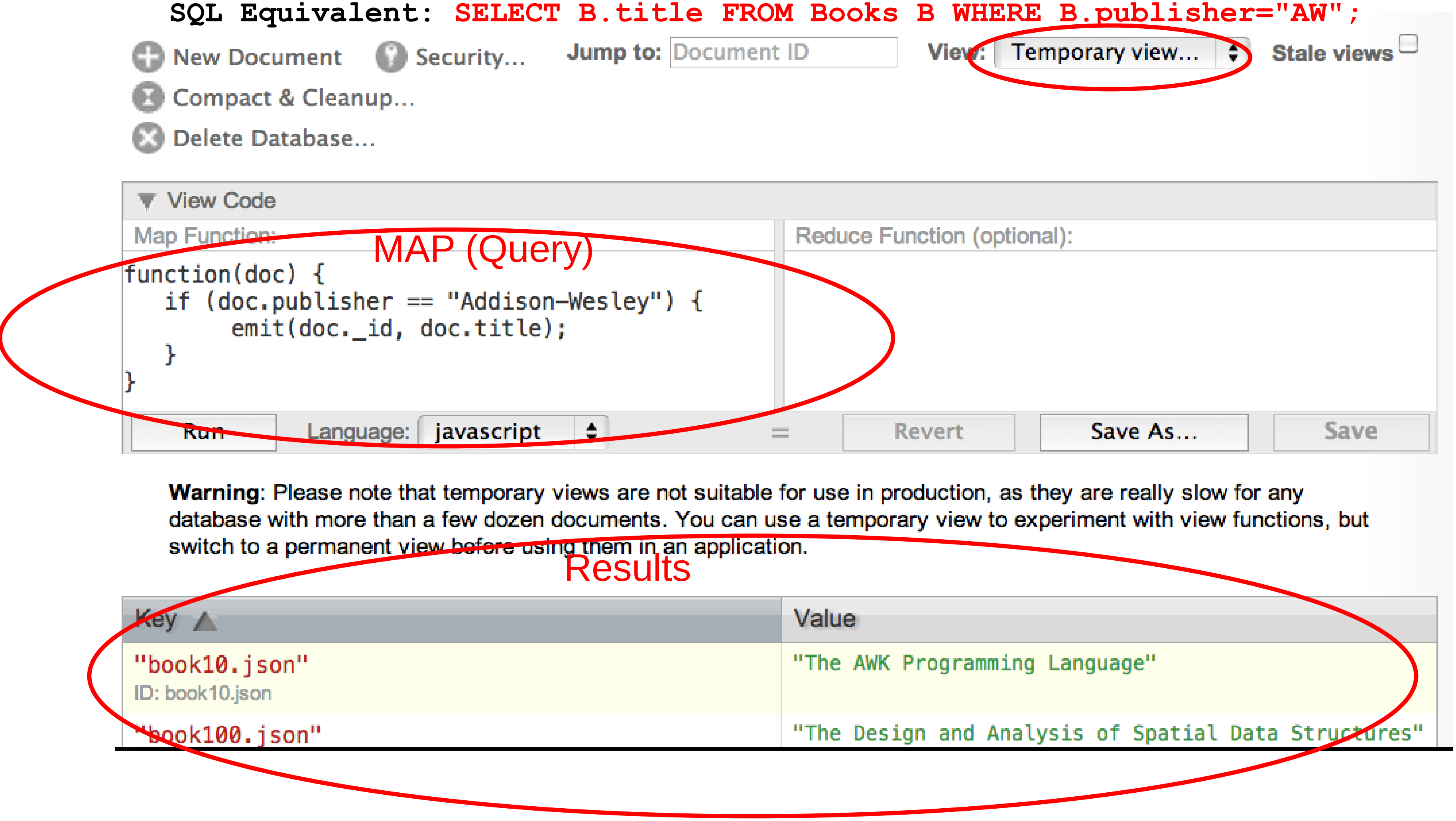
Warning: Please note that temporary views are not suitable for use in production, as they are really slow for any database with more than a few dozen documents. You can use a temporary view to experiment with view functions, but switch to a permanent view before using them in an application.

Results

Key	Value
"book1.json" ID: book1.json	"Modern Database Systems: The Object Model, Interoperability, and Beyond."
"book10.json" ID: book10.json	"The AWK Programming Language"

CouchDB: SELECT-WHERE QUERY (with FUTON)

SQL Equivalent: SELECT B.title FROM Books B WHERE B.publisher="AW";



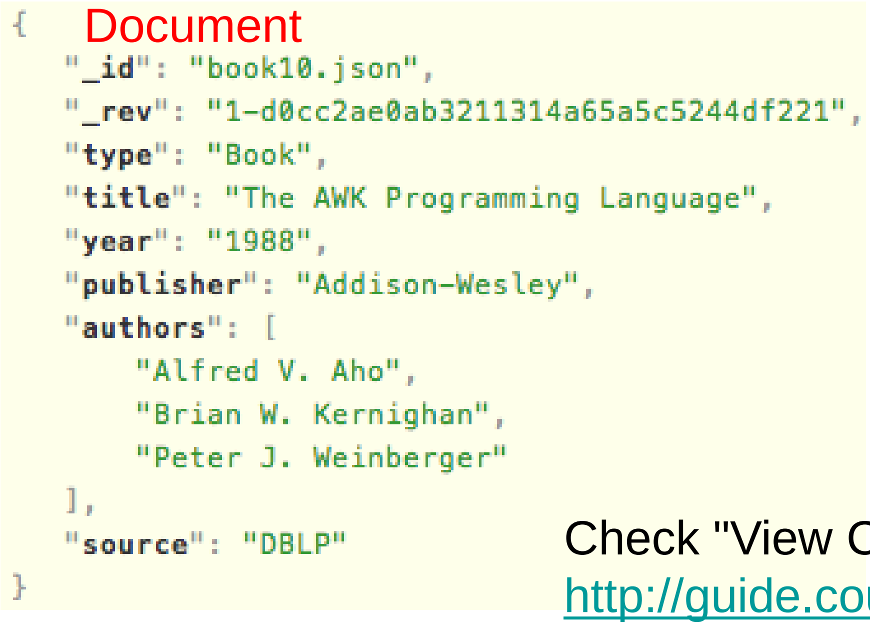
```
function(doc) {
   if (doc.publisher == "Addison-Wesley") {
        emit(doc._id, doc.title);
   }
}
```

Warning: Please note that temporary views are not suitable for use in production, as they are really slow for any database with more than a few dozen documents. You can use a temporary view to experiment with view functions, but switch to a permanent view before using them in an application.

Key	Value
"book10.json" ID: book10.json	"The AWK Programming Language"
"book100.json"	"The Design and Analysis of Spatial Data Structures"

CouchDB: Array Object Iteration (with FUTON)

Document



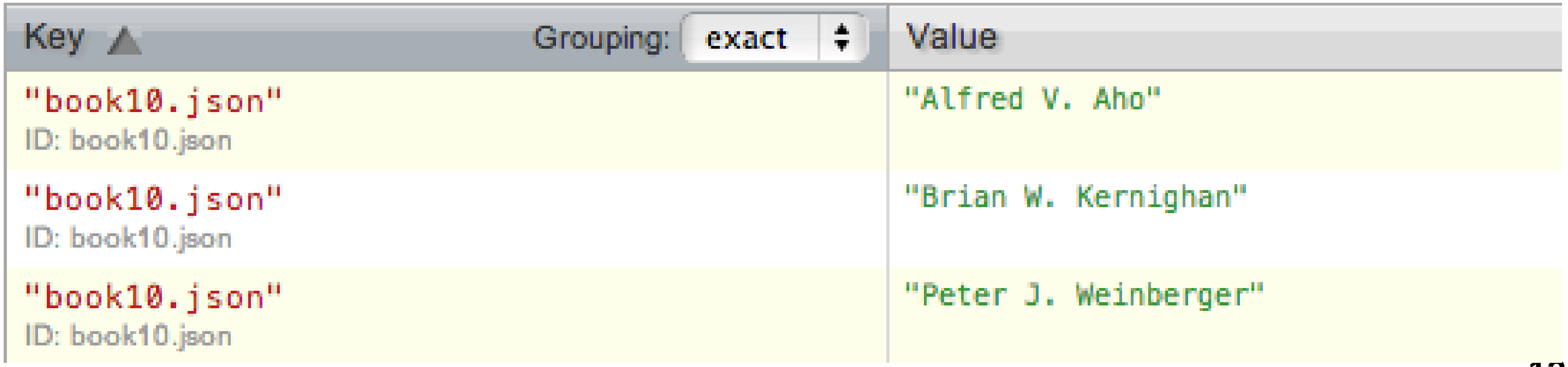
```
{
  "_id": "book10.json",
  "_rev": "1-d0cc2ae0ab3211314a65a5c5244df221",
  "type": "Book",
  "title": "The AWK Programming Language",
  "year": "1988",
  "publisher": "Addison-Wesley",
  "authors": [
      "Alfred V. Aho",
      "Brian W. Kernighan",
      "Peter J. Weinberger"
  ],
  "source": "DBLP"
}
```

Map Function

```
function(doc) {
    for (i in doc.authors) {
      author = doc.authors[i];
      emit(doc._id, author);
    }
}
```

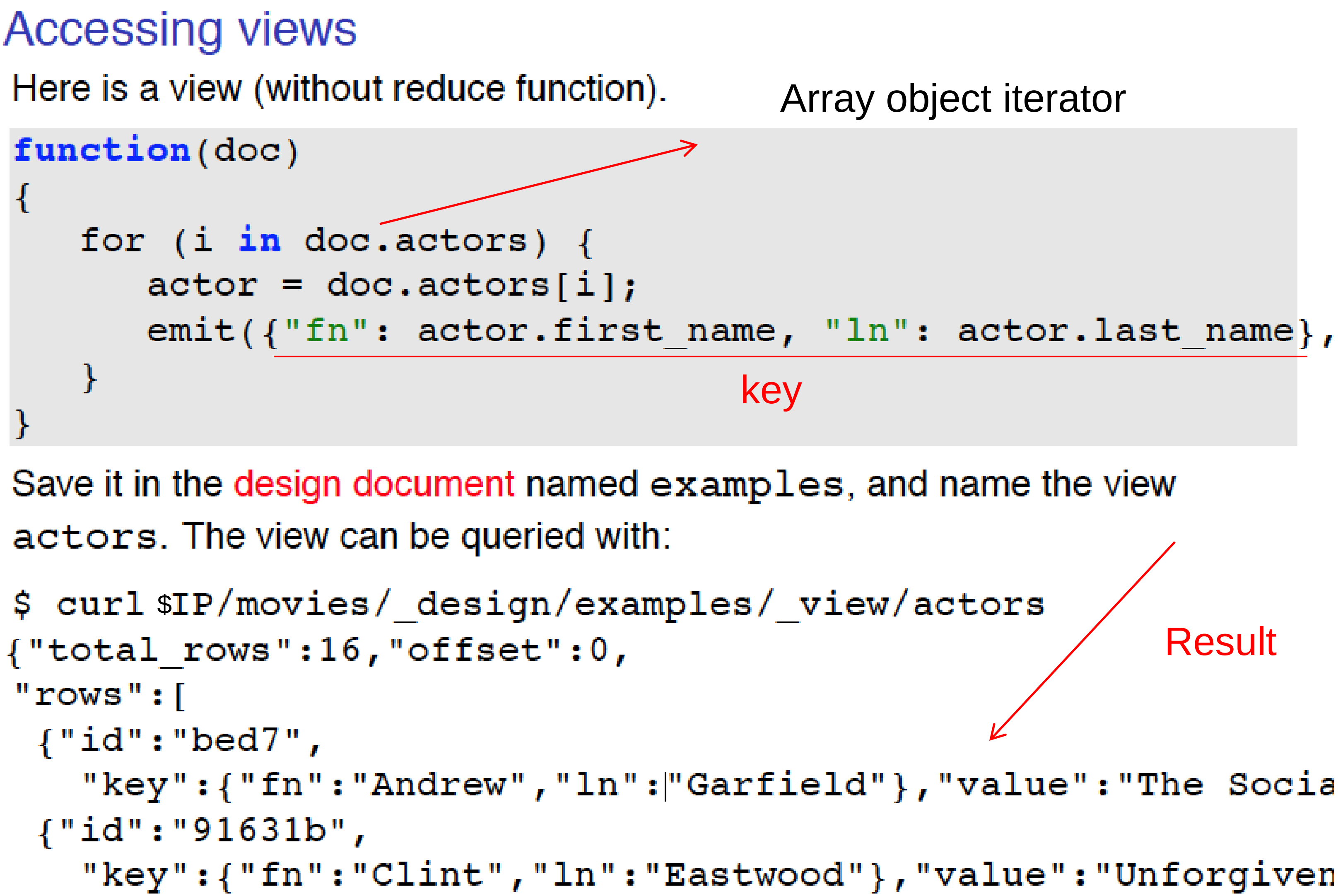
Check "View Cookbook for SQL Jockeys" for more!
http://guide.couchdb.org/editions/1/en/cookbook.html

Results



Key ▲ Grouping: exact	Value
"book10.json" ID: book10.json	"Alfred V. Aho"
"book10.json" ID: book10.json	"Brian W. Kernighan"
"book10.json" ID: book10.json	"Peter J. Weinberger"

CouchDB: Array Object Iteration (with FUTON + CURL)



Accessing views

Here is a view (without reduce function).

```
function(doc)
{
   for (i in doc.actors) {
      actor = doc.actors[i];
      emit({"fn": actor.first_name, "ln": actor.last_name},
   }
}
```

Save it in the design document named `examples`, and name the view `actors`. The view can be queried with:

```
$ curl $IP/movies/_design/examples/_view/actors
{"total_rows":16,"offset":0,
"rows":[
 {"id":"bed7",
   "key":{"fn":"Andrew","ln":"Garfield"},"value":"The Socia
 {"id":"91631b",
   "key":{"fn":"Clint","ln":"Eastwood"},"value":"Unforgiven
```

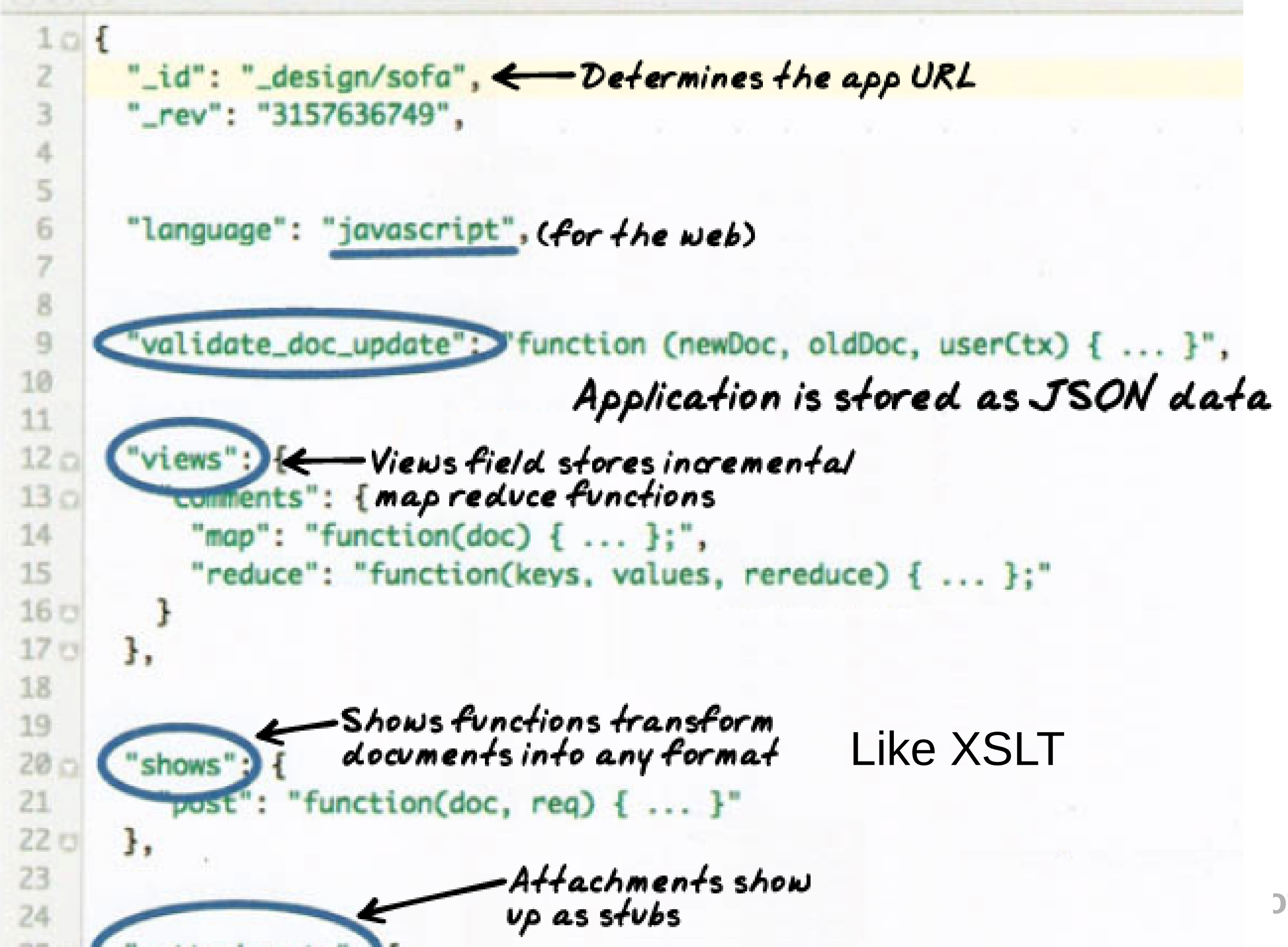
Array object iterator

key

Result

CouchDB: Design Documents (Apps are Documents!)

A Design document is a CouchDB document with an id that begins with _design/. These documents store the materialized view code + other code (e.g., for tranforming data to HTML, etc.)



```
{
  "_id": "_design/sofa",
  "_rev": "3157636749",


  "language": "javascript",


  "validate_doc_update": "function (newDoc, oldDoc, userCtx) { ... }",


  "views": {
    "comments": {
      "map": "function(doc) { ... };",
      "reduce": "function(keys, values, rereduce) { ... };"
    }
  },


  "shows": {
    "post": "function(doc, req) { ... }"
  },


```

Determines the app URL

(for the web)

Application is stored as JSON data

Views field stores incremental map reduce functions

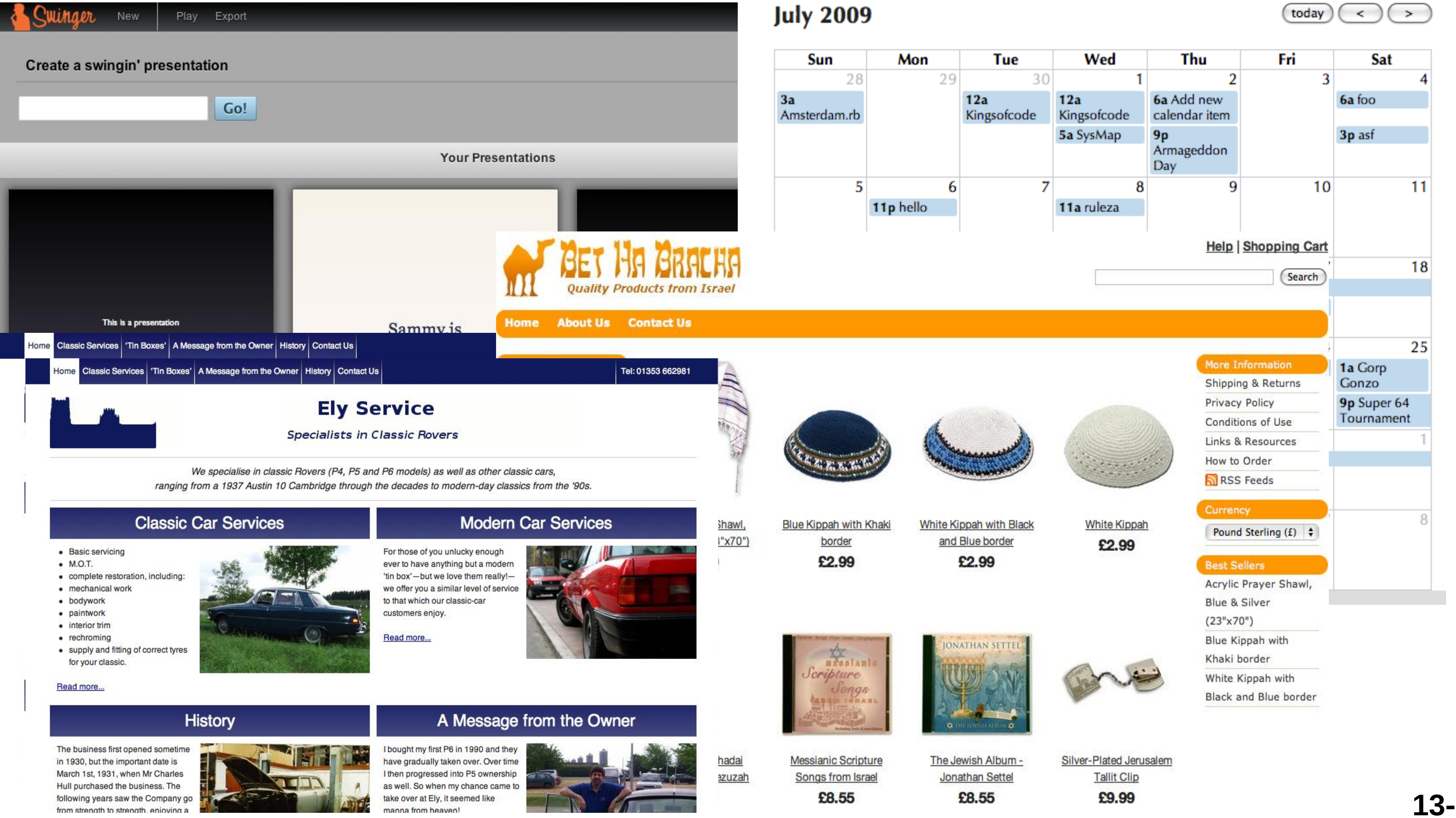
Shows functions transform documents into any format

Like XSLT

Attachments show up as stubs

CouchDB: Design Documents (Apps are Documents!)

CouchDB Design Documents can lead to "Standalone Web Apps"



Create a swingin' presentation

Your Presentations

July 2009

Sun	Mon	Tue	Wed	Thu	Fri	Sat
28 3a Amsterdam.rb	29	30 12a Kingsofcode	1 12a Kingsofcode 5a SysMap	2 6a Add new calendar item 9p Armageddon Day	3	4 6a foo 3p asf
5	6 11p hello	7	8 11a ruleza	9	10	11
						18
						25 1a Gorp Gonzo 9p Super 64 Tournament
						1
						8

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Best Sellers
- Acrylic Prayer Shawl, Blue & Silver (23"x70")
- Blue Kippah with Khaki border
- White Kippah with Black and Blue border

Shawl, "x70")	Blue Kippah with Khaki border £2.99	White Kippah with Black and Blue border £2.99	White Kippah £2.99
hadai ezuzah	Messianic Scripture Songs from Israel £8.55	The Jewish Album - Jonathan Settel £8.55	Silver-Plated Jerusalem Tallit Clip £9.99

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- complete restoration, including:
- mechanical work
- bodywork
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- interior trim
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- supply and fitting of correct tyres for your classic.

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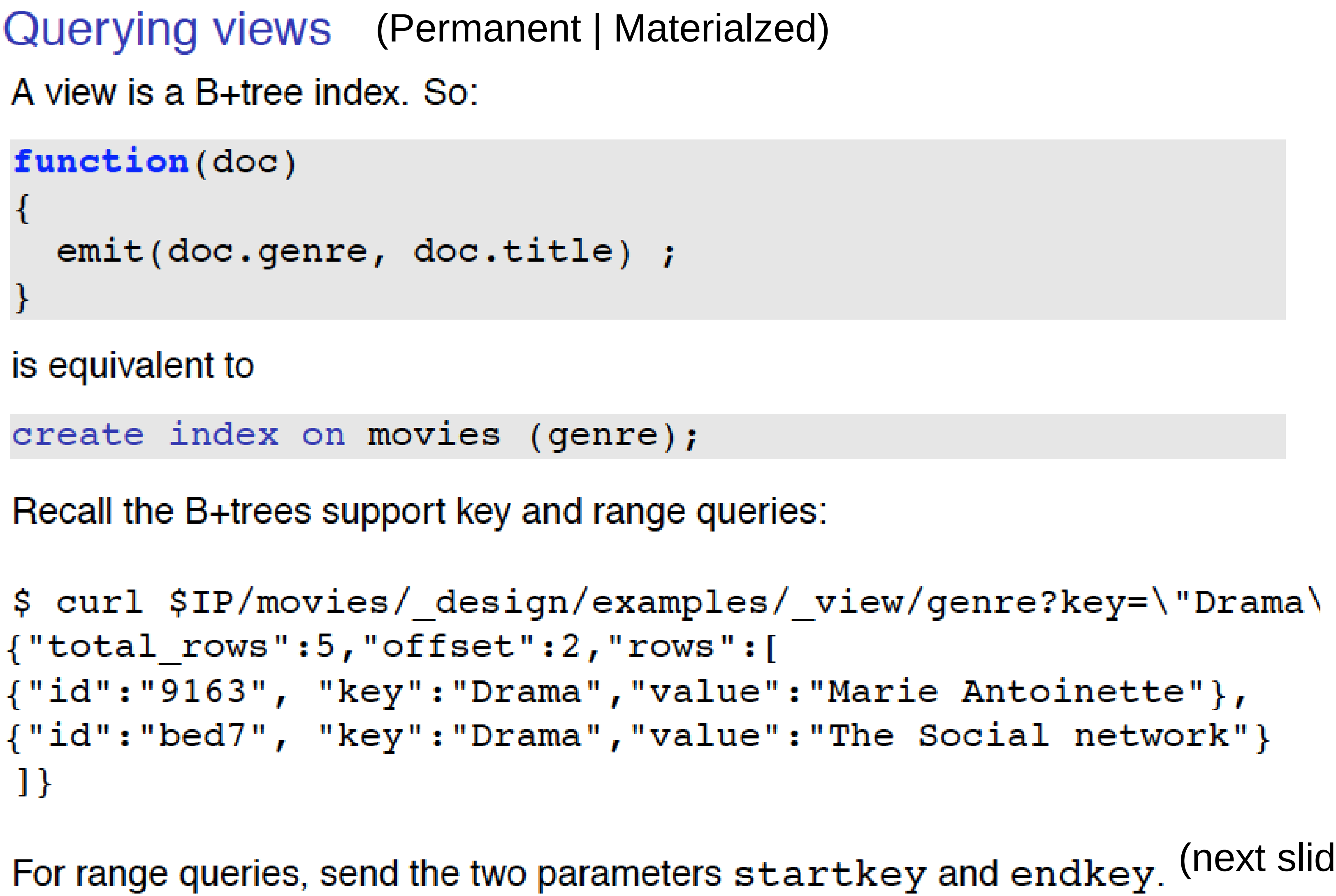
History

The business first opened sometime in 1930, but the important date is March 1st, 1931, when Mr Charles Hull purchased the business. The following years saw the Company go from strength to strength, enjoying a

A Message from the Owner

I bought my first P6 in 1990 and they have gradually taken over. Over time I then progressed into P5 ownership as well. So when my chance came to take over at Ely, it seemed like manna from heaven!

CouchDB: Querying Materialized Views (with FUTON)



Querying views

(Permanent | Materialzed)

A view is a B+tree index. So:

```
function(doc)
{
  emit(doc.genre, doc.title) ;
}
```

is equivalent to

```
create index on movies (genre);
```

Recall the B+trees support key and range queries:

```
$ curl $IP/movies/_design/examples/_view/genre?key=\"Drama\
{"total_rows":5,"offset":2,"rows":[
{"id":"9163", "key":"Drama","value":"Marie Antoinette"},
{"id":"bed7", "key":"Drama","value":"The Social network"}
]}
```

For range queries, send the two parameters `startkey` and `endkey`. (next slide)

CouchDB: Range Queries (with CURL)

CURL Command

```
curl -X GET
http://127.0.0.1:5984/books/_design/authors/_view/autho
rs?startkey=\"book980.json\"&endkey=\"books998.json\"
```

Results

View count

First result occurence

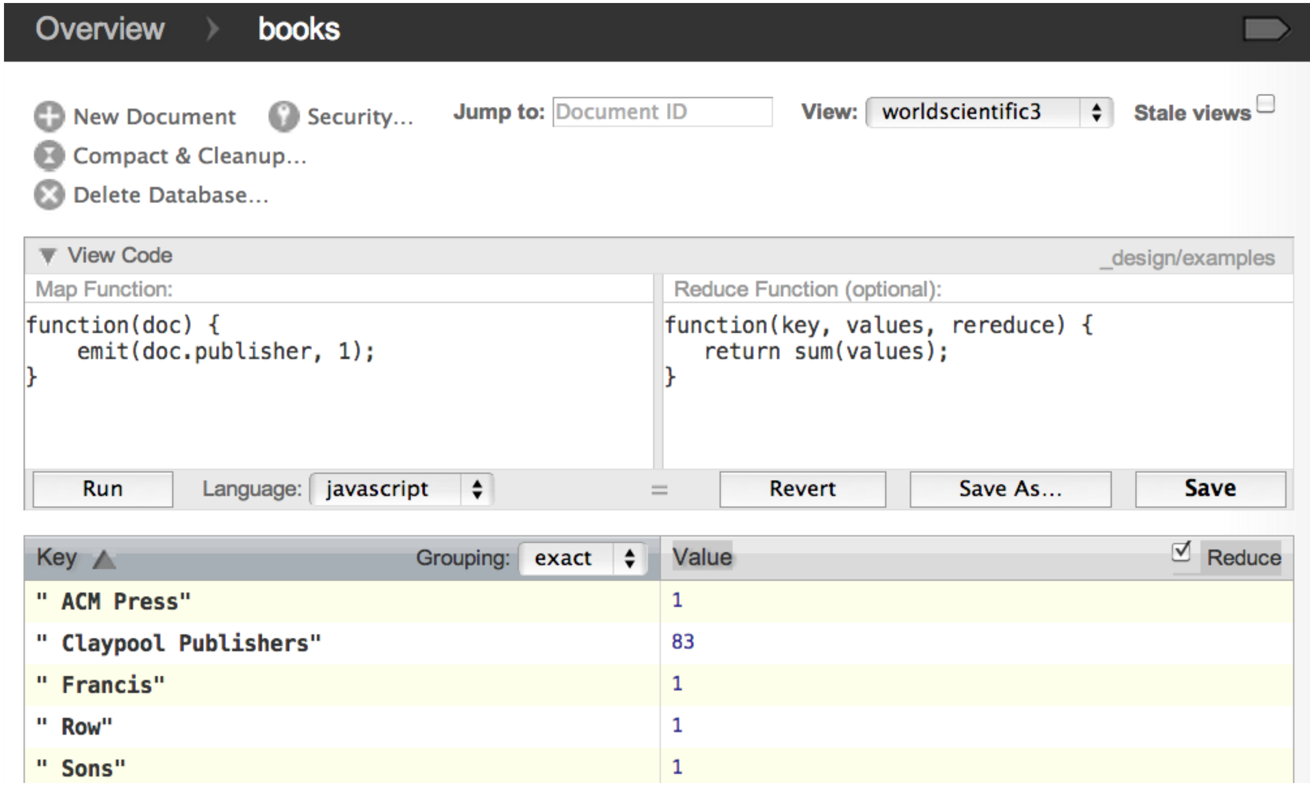
```
$ {"total_rows":1893,"offset":1871,"rows":[
{"id":"book980.json","key":"book980.json","value":"A. J. Kfoury"},
{"id":"book980.json","key":"book980.json","value":"Michael A. Arbib"},
{"id":"book980.json","key":"book980.json","value":"Robert N. Moll"},
{"id":"book981.json","key":"book981.json","value":"Peter D. Mosses"},
{"id":"book982.json","key":"book982.json","value":"Anne Mulkers"},
{"id":"book983.json","key":"book983.json","value":"ller"},
{"id":"book984.json","key":"book984.json","value":"ller"},
```

CouchDB Querying with Aggregation (Map & Reduce)

90% of queries will be MAP queries.

REDUCE allows us to carry out aggregation on a given field.

SQL:
SELECT key, sum(key)
FROM Books
GROUP BY key



Jump to: Document ID

View: worldscientific3

_design/examples

Map Function:

```
function(doc) {
    emit(doc.publisher, 1);
}
```

Reduce Function (optional):

```
function(key, values, rereduce) {
   return sum(values);
}
```

Language: javascript

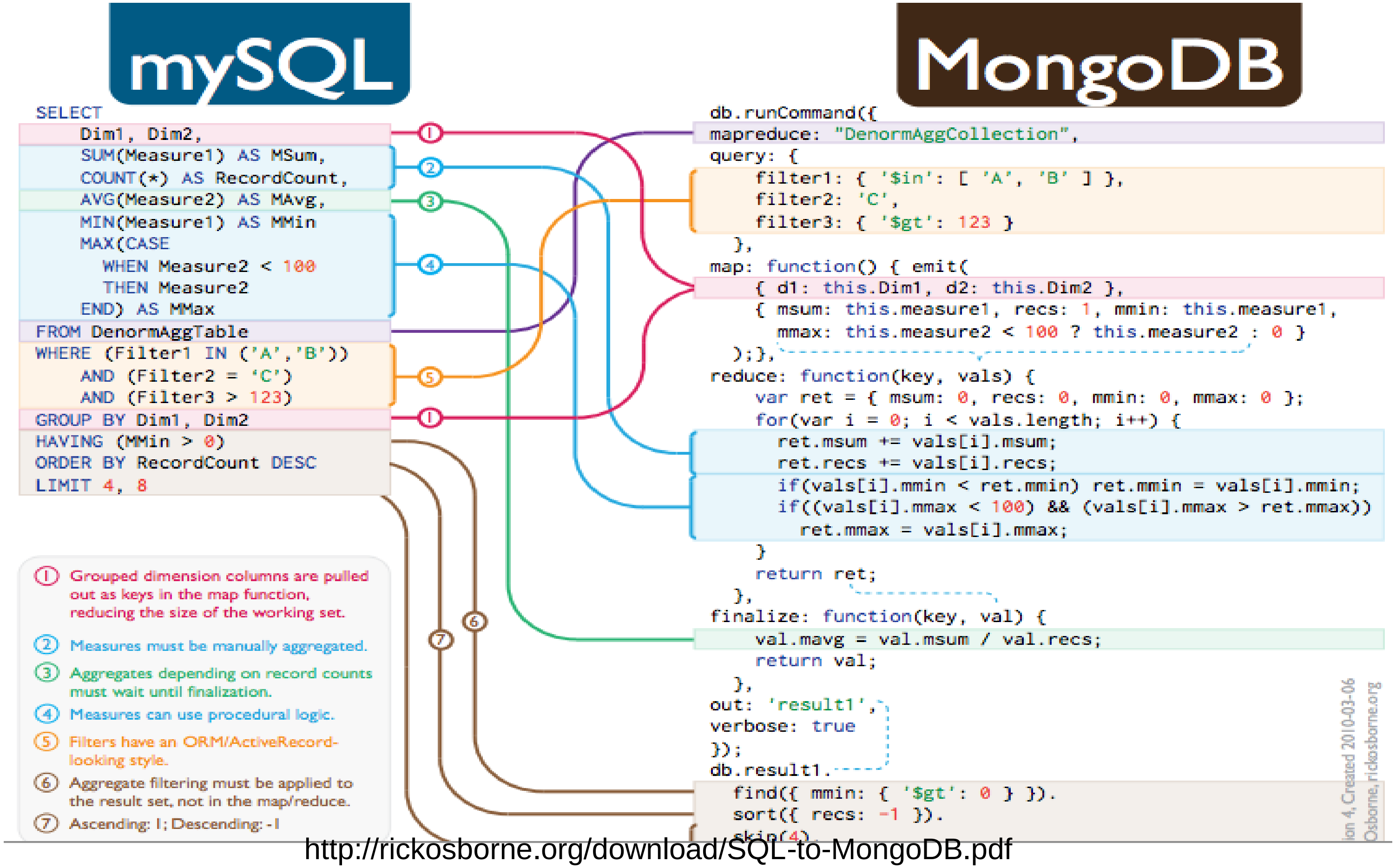
Grouping: exact

☑ Reduce

Key	Value
" ACM Press"	1
" Claypool Publishers"	83
" Francis"	1
" Row"	1
" Sons"	1

Complex Map & Reduce

For a real app we could envision much more complex queries.



```sql
SELECT
    Dim1, Dim2,
    SUM(Measure1) AS MSum,
    COUNT(*) AS RecordCount,
    AVG(Measure2) AS MAvg,
    MIN(Measure1) AS MMin
    MAX(CASE
      WHEN Measure2 < 100
      THEN Measure2
    END) AS MMax
FROM DenormAggTable
WHERE (Filter1 IN ('A','B'))
    AND (Filter2 = 'C')
    AND (Filter3 > 123)
GROUP BY Dim1, Dim2
HAVING (MMin > 0)
ORDER BY RecordCount DESC
LIMIT 4, 8
```

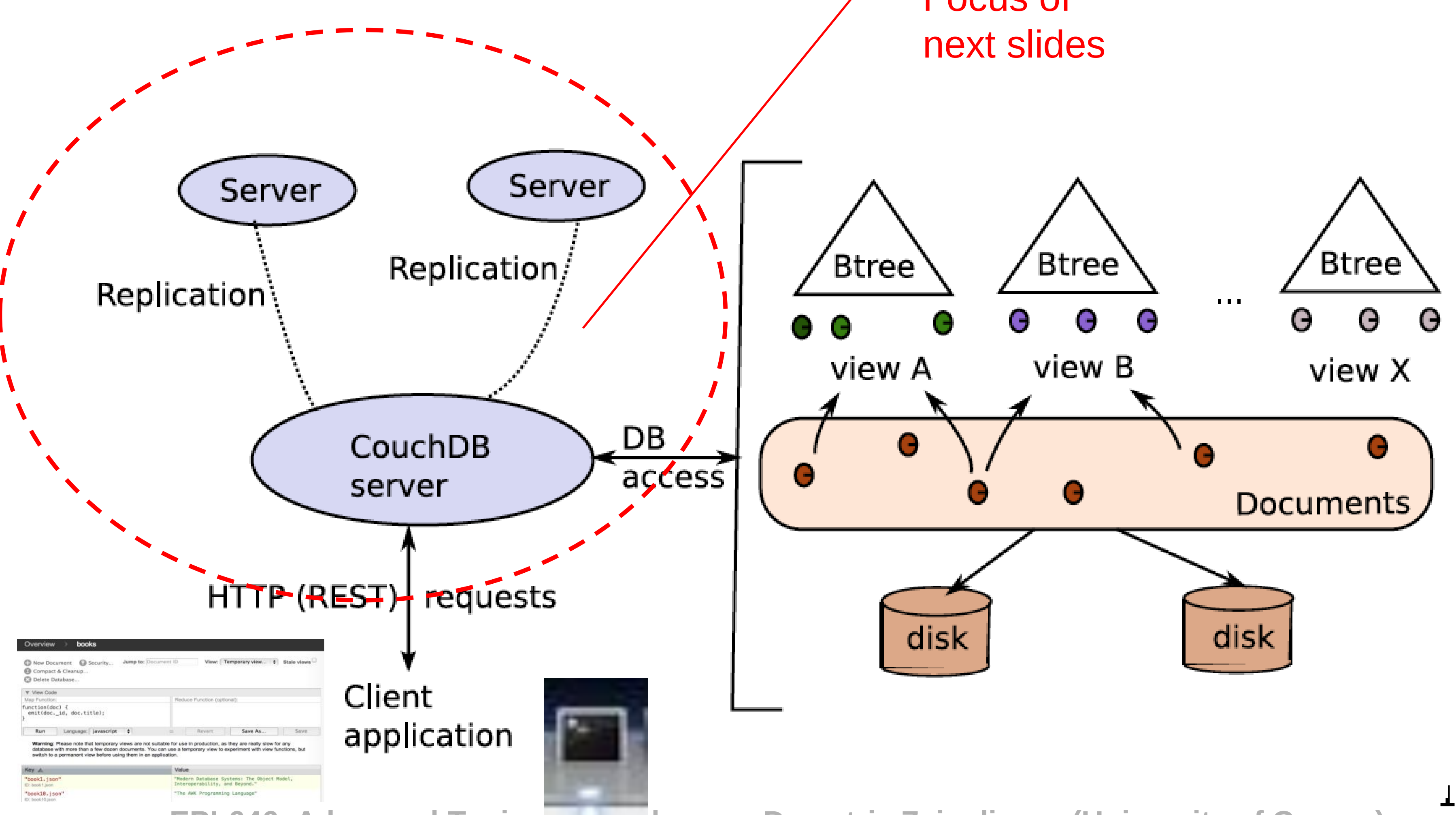
```javascript
db.runCommand({
mapreduce: "DenormAggCollection",
query: {
    filter1: { '$in': [ 'A', 'B' ] },
    filter2: 'C',
    filter3: { '$gt': 123 }
  },
map: function() { emit(
    { d1: this.Dim1, d2: this.Dim2 },
    { msum: this.measure1, recs: 1, mmin: this.measure1,
      mmax: this.measure2 < 100 ? this.measure2 : 0 }
  );},
reduce: function(key, vals) {
    var ret = { msum: 0, recs: 0, mmin: 0, mmax: 0 };
    for(var i = 0; i < vals.length; i++) {
      ret.msum += vals[i].msum;
      ret.recs += vals[i].recs;
      if(vals[i].mmin < ret.mmin) ret.mmin = vals[i].mmin;
      if((vals[i].mmax < 100) && (vals[i].mmax > ret.mmax))
        ret.mmax = vals[i].mmax;
    }
    return ret;
  },
finalize: function(key, val) {
    val.mavg = val.msum / val.recs;
    return val;
  },
out: 'result1',
verbose: true
});
db.result1.
  find({ mmin: { '$gt': 0 } }).
  sort({ recs: -1 }).
  skip(4).
```

1. Grouped dimension columns are pulled out as keys in the map function, reducing the size of the working set.
2. Measures must be manually aggregated.
3. Aggregates depending on record counts must wait until finalization.
4. Measures can use procedural logic.
5. Filters have an ORM/ActiveRecord-looking style.
6. Aggregate filtering must be applied to the result set, not in the map/reduce.
7. Ascending: 1; Descending: -1

http://rickosborne.org/download/SQL-to-MongoDB.pdf

CouchDB Replication

Architecture of CouchDB



Focus of next slides

Overview › books

⊕ New Document ⊙ Security... Jump to: Document ID View: Temporary view... Stale views □
⊙ Compact & Cleanup...
⊗ Delete Database...

▼ View Code

Map Function:

```
function(doc) {
  emit(doc._id, doc.title);
}
```

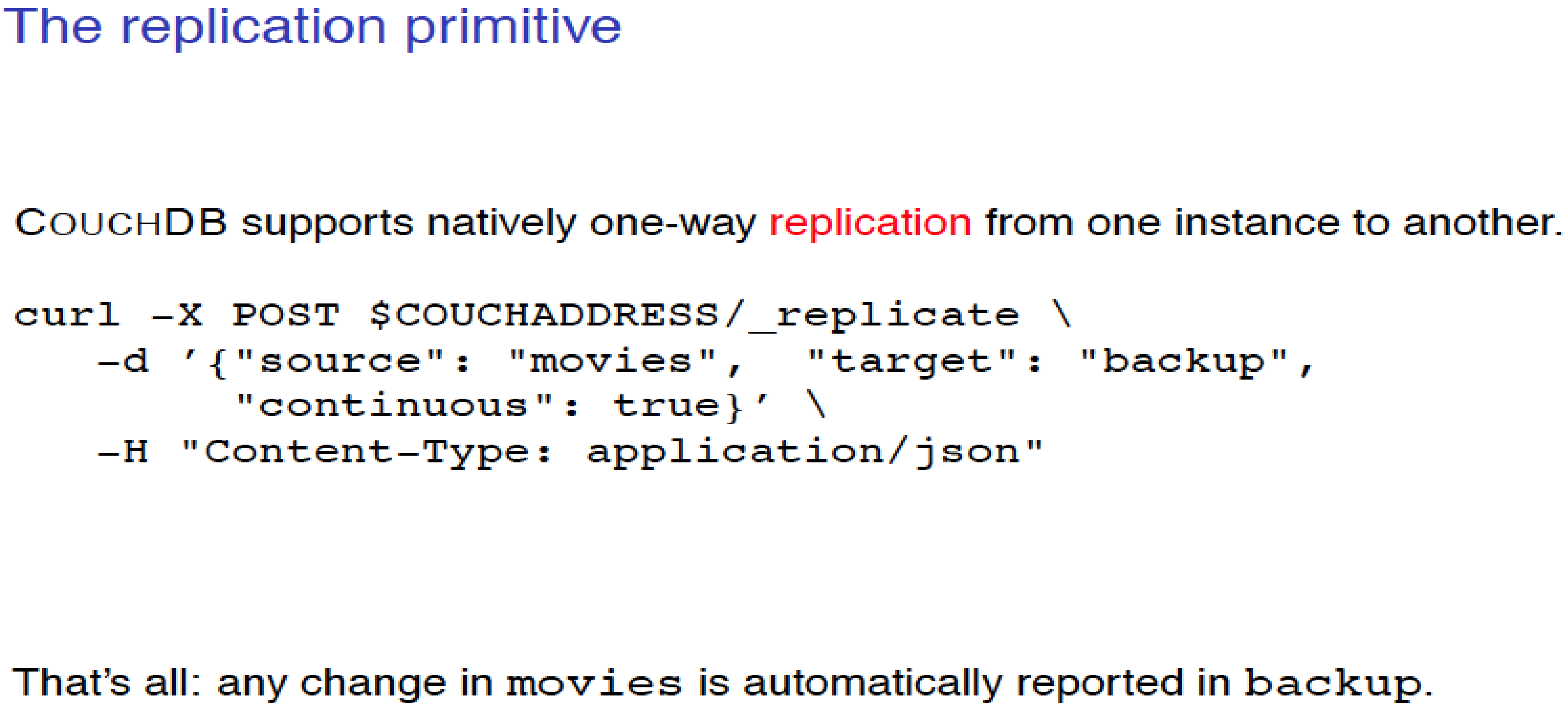
Reduce Function (optional):

Run Language: javascript Revert Save As... Save

Warning: Please note that temporary views are not suitable for use in production, as they are really slow for any database with more than a few dozen documents. You can use a temporary view to experiment with view functions, but switch to a permanent view before using them in an application.

Key ▲	Value
"book1.json" ID: book1.json	"Modern Database Systems: The Object Model, Interoperability, and Beyond."
"book10.json" ID: book10.json	"The AWK Programming Language"

CouchDB One-way/Symmetric Replication (with CURl)



The replication primitive

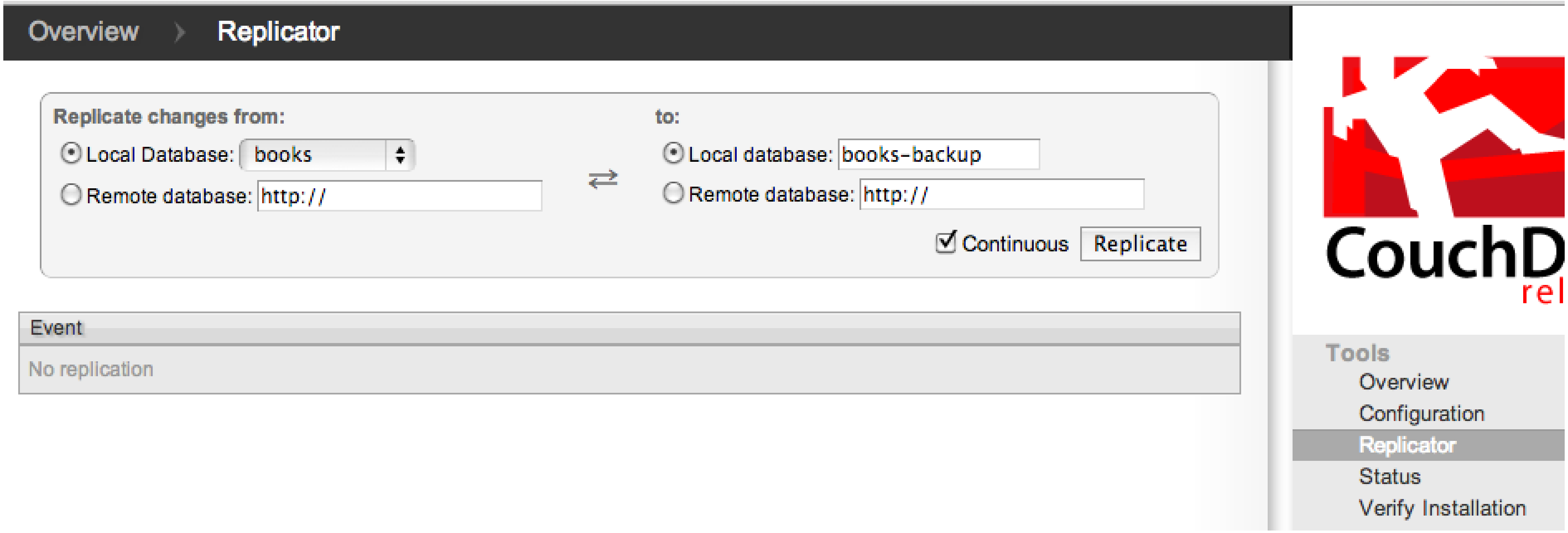
COUCHDB supports natively one-way replication from one instance to another.

```
curl -X POST $COUCHADDRESS/_replicate \
   -d '{"source": "movies",  "target": "backup",
        "continuous": true}' \
   -H "Content-Type: application/json"
```

That's all: any change in `movies` is automatically reported in `backup`.

Two way replication can be achieved by executing the inverse statement as well.

CouchDB One-way/Symmetric Replication (with CURL)



Replicate changes from:

● Local Database: books

○ Remote database: http://

to:

● Local database: books-backup

○ Remote database: http://

☑ Continuous

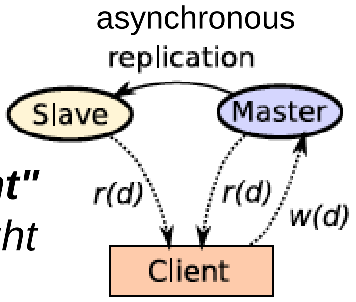
Event
No replication

CouchDB Distribution (Concepts)

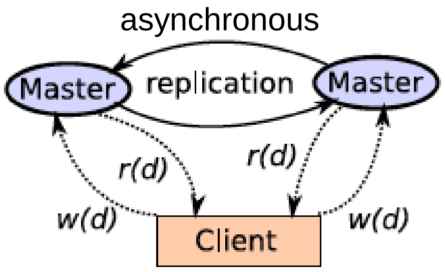
Distribution strategies

Combine a proxy that distributes requests, with the replication feature of CouchDB.

"Eventually Consistent"
(reading from slave might be outdated)



a - Master-slave arch.



b - Master-master arch.

"Conflict Management is Necessary "

```
function(doc) {
   if (doc._conflicts) {
     emit(doc._conflicts, null);
   }
}
```

CouchDB Security

- CouchDB allows any request to be made by anyone (i.e., by default admin).
  - By default, CouchDB will listen only on your loopback network interface (127.0.0.1 or localhost) and thus only you will be able to make requests to CouchDB, nobody else.
- If you don’t like that, you can create specific admin users with a username and password as their credentials.
- You could also add **validation functions** to your design documents that will make sure that the right people make the right changes.
- **Securing CouchDB is outside the scope of this lecture… The same applies to web programming with CouchDB.**