This talk explores why Postgres is uniquely capable of functioning as a central database in enterprises. *Title concept from Josh Berkus*
1. Object-relational (extensibility)
2. NoSQL
3. Data analytics
4. Foreign data wrappers (database federation)
5. Central role
Object-relational databases like Postgres support classes and inheritance, but most importantly, they define database functionality as objects that can be easily manipulated.

Example: ISBN Data Type

CREATE EXTENSION isn;

\dT

List of data types

<table>
<thead>
<tr>
<th>Schema</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>public</td>
<td>ean13</td>
<td>International European Article Number (EAN13)</td>
</tr>
<tr>
<td>public</td>
<td>ismn</td>
<td>International Standard Music Number (ISMN)</td>
</tr>
<tr>
<td>public</td>
<td>ismn13</td>
<td>International Standard Music Number 13 (ISMN13)</td>
</tr>
<tr>
<td>public</td>
<td>issn</td>
<td>International Standard Serial Number (ISSN)</td>
</tr>
<tr>
<td>public</td>
<td>issn13</td>
<td>International Standard Serial Number 13 (ISSN13)</td>
</tr>
<tr>
<td>public</td>
<td>upc</td>
<td>Universal Product Code (UPC)</td>
</tr>
</tbody>
</table>

http://www.postgresql.org/docs/current/isn.html
ISBN Behaves Just Like Built-In Types

\dTS
...
  pg_catalog | integer  | -2 billion to 2 billion integer, 4-byte storage
...
The System Catalog Entry for INTEGER

```
SELECT * FROM pg_type WHERE typname = 'int4';
```

<table>
<thead>
<tr>
<th>Field</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>typname</td>
<td>int4</td>
</tr>
<tr>
<td>typnamespace</td>
<td>11</td>
</tr>
<tr>
<td>typowner</td>
<td>10</td>
</tr>
<tr>
<td>typlen</td>
<td>4</td>
</tr>
<tr>
<td>typbyval</td>
<td>t</td>
</tr>
<tr>
<td>typtype</td>
<td>b</td>
</tr>
<tr>
<td>typcategory</td>
<td>N</td>
</tr>
<tr>
<td>typispreferred</td>
<td>f</td>
</tr>
<tr>
<td>typisdefined</td>
<td>t</td>
</tr>
<tr>
<td>typdelim</td>
<td>,</td>
</tr>
<tr>
<td>typrelid</td>
<td>0</td>
</tr>
<tr>
<td>typelem</td>
<td>0</td>
</tr>
<tr>
<td>typarray</td>
<td>1007</td>
</tr>
<tr>
<td>typinput</td>
<td>int4in</td>
</tr>
<tr>
<td>typoutput</td>
<td>int4out</td>
</tr>
<tr>
<td>typreceive</td>
<td>int4recv</td>
</tr>
<tr>
<td>typesend</td>
<td>int4send</td>
</tr>
<tr>
<td>typmodin</td>
<td>-</td>
</tr>
<tr>
<td>typmodout</td>
<td>-</td>
</tr>
<tr>
<td>typanalyze</td>
<td>-</td>
</tr>
</tbody>
</table>

...
### The System Catalog Entry for ISBN

```sql
SELECT * FROM pg_type WHERE typname = 'isbn';
```

- `[ RECORD 1 ]`--+-

<table>
<thead>
<tr>
<th>typname</th>
<th>isbn</th>
</tr>
</thead>
<tbody>
<tr>
<td>typnamespace</td>
<td>2200</td>
</tr>
<tr>
<td>typowner</td>
<td>10</td>
</tr>
<tr>
<td>typlen</td>
<td>8</td>
</tr>
<tr>
<td>typbyval</td>
<td>t</td>
</tr>
<tr>
<td>typtype</td>
<td>b</td>
</tr>
<tr>
<td>typcategory</td>
<td>U</td>
</tr>
<tr>
<td>typispreferred</td>
<td>f</td>
</tr>
<tr>
<td>typisdefined</td>
<td>t</td>
</tr>
<tr>
<td>typdelim</td>
<td>,</td>
</tr>
<tr>
<td>typreloid</td>
<td>0</td>
</tr>
<tr>
<td>typelem</td>
<td>0</td>
</tr>
<tr>
<td>typarray</td>
<td>16405</td>
</tr>
<tr>
<td>typinput</td>
<td>isbn_in</td>
</tr>
<tr>
<td>typoutput</td>
<td>public.isn_out</td>
</tr>
<tr>
<td>typreceive</td>
<td>-</td>
</tr>
<tr>
<td>typesend</td>
<td>-</td>
</tr>
<tr>
<td>typmodin</td>
<td>-</td>
</tr>
<tr>
<td>typmodout</td>
<td>-</td>
</tr>
<tr>
<td>typanalyze</td>
<td>-</td>
</tr>
</tbody>
</table>

...
CREATE EXTENSION plpythonu;

\dL

List of languages

<table>
<thead>
<tr>
<th>Name</th>
<th>Owner</th>
<th>Trusted</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>plpgsql</td>
<td>postgres</td>
<td>t</td>
<td>PL/pgSQL procedural language</td>
</tr>
<tr>
<td>plpythonu</td>
<td>postgres</td>
<td>f</td>
<td>PL/PythonU untrusted procedural language</td>
</tr>
</tbody>
</table>

http://www.postgresql.org/docs/current/plpython.html
Available Languages

- PL/Java
- PL/Perl
- PL/pgSQL (like PL/SQL)
- PL/PHP
- PL/Python
- PL/R (like SPSS)
- PL/Ruby
- PL/Scheme
- PL/sh
- PL/Tcl
- PL/v8 (JavaScript)
- SPI (C)

http://www.postgresql.org/docs/current/external-pl.html
Specialized Indexing Methods

- BRIN
- BTree
- Hash
- GIN (generalized inverted index)
- GiST (generalized search tree)
- SP-GiST (space-partitioned GiST)

http://www.postgresql.org/docs/current/indexam.html
Index Types Are Defined in the System Catalogs Too

SELECT amname FROM pg_am ORDER BY 1;

<table>
<thead>
<tr>
<th>amname</th>
</tr>
</thead>
<tbody>
<tr>
<td>brin</td>
</tr>
<tr>
<td>btree</td>
</tr>
<tr>
<td>hash</td>
</tr>
<tr>
<td>gin</td>
</tr>
<tr>
<td>gist</td>
</tr>
<tr>
<td>spgist</td>
</tr>
</tbody>
</table>

http://www.postgresql.org/docs/current/catalog-pg-am.html
Operators Have Similar Flexibility

Operators are function calls with left and right arguments of specified types:

\[ \text{Schema} \mid \text{Name} \mid \text{Left arg type} \mid \text{Right arg type} \mid \text{Result type} \mid \text{Description} \]

<table>
<thead>
<tr>
<th>Schema</th>
<th>Name</th>
<th>Left arg type</th>
<th>Right arg type</th>
<th>Result type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pg_catalog</td>
<td>+</td>
<td>integer</td>
<td>integer</td>
<td>integer</td>
<td>add</td>
</tr>
</tbody>
</table>

\[ \text{Schema} \mid \text{Name} \mid \text{Result data type} \mid \text{Argument data types} \mid \text{Type} \]

<table>
<thead>
<tr>
<th>Schema</th>
<th>Name</th>
<th>Result data type</th>
<th>Argument data types</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>pg_catalog</td>
<td>int4pl</td>
<td>integer</td>
<td>integer, integer</td>
<td>normal</td>
</tr>
</tbody>
</table>
Other Extensibility

- Aggregates are defined in `pg_aggregate`, `sum(int4)`
- Casts are defined in `pg_cast`, `int4(float8)`
Externally Developed Plug-Ins

- PostGIS (Geographical Information System)
- PL/v8 (server-side JavaScript)
- experimentation, e.g., full text search was originally externally developed
Offshoots of Postgres

- Aurora (Amazon)
- AsterDB
- Greenplum
- Informix
- Netezza
- ParAccel
- Postgres XC
- Redshift (Amazon)
- Truviso
- Vertica
- Yahoo! Everest

https://wiki.postgresql.org/wiki/PostgreSQL-derived_databases
http://de.slideshare.net/pgconf/elephant-roads-a-tour-of-postgres-forks
Offshoots of Postgres

https://raw.githubusercontent.com/daamien/artwork/master/inkscape/PostgreSQL_timeline/timeline_postgresql.png
Many databases treat extensions as special cases, with serious limitations. Postgres built-ins use the same API as extensions, so all extensions operate just like built-in functionality.
Extensions and Built-In Facilities
Behave the Same

Postgres System Tables

- sum()
- int4
- btree
- PL/pgSQL

Extensions

- ISN
- PostGIS
- PL/R
2. NoSQL
There is no single NoSQL technology. They all take different approaches and have different features and drawbacks:

- Key-value stores, e.g., Redis
- Document databases, e.g., MongoDB (JSON)
- Columnar stores: Cassandra
- Graph databases: Neo4j
Why NoSQL Exists

Generally, NoSQL is optimized for:

- Auto-sharding
- Fast simple queries
- Flexible schemas
NoSQL Sacrifices

- A powerful query language
- A sophisticated query optimizer
- Data normalization
- Joins
- Referential integrity
- Durability
Are These Drawbacks Worth the Cost?

- **Difficult Reporting** Data must be brought to the client for analysis, e.g., no aggregates or data analysis functions. Schema-less data requires complex client-side knowledge for processing.

- **Complex Application Design** Without powerful query language and query optimizer, the client software is responsible for efficiently accessing data and for data consistency.

- **Durability** Administrators are responsible for data retention.
When Should NoSQL Be Used?

- Massive write scaling is required, more than a single server can provide
- Only simple data access pattern is required
- Additional resource allocation for development is acceptable
- Strong data retention or transactional guarantees are not required
- Unstructured duplicate data that greatly benefits from column compression
When Should Relational Storage Be Used?

- Easy administration
- Variable workloads and reporting
- Simplified application development
- Strong data retention
Postgres has many NoSQL features without the drawbacks:

- Schema-less data types, with sophisticated indexing support
- Transactional schema changes with rapid additional and removal of columns
- Durability by default, but controllable per-table or per-transaction
CREATE TABLE customer (id SERIAL, data JSONB);

INSERT INTO customer VALUES (DEFAULT, '{"name" : "Bill", "age" : 21}');

SELECT data->>'name' FROM customer WHERE data->>'age' = '21';

?column?

---------
"Bill"
BEGIN WORK;
ALTER TABLE customer ADD COLUMN debt_limit NUMERIC(10,2);
ALTER TABLE customer ADD COLUMN creation_date TIMESTAMP WITH TIME ZONE;
ALTER TABLE customer RENAME TO cust;
COMMIT;
3. Data Analytics

- Aggregates
- Optimizer
- Server-side languages, e.g., PL/R
- Window functions
- Bitmap heap scans
- Tablespaces
- Data partitioning
- Materialized views
- Common table expressions (CTE)
- BRIN indexes
- GROUPING SETS, ROLLUP, CUBE
- Just-in-time compilation (JIT)
- Parallelism
- Sharding (in progress)

http://www.slideshare.net/PGExperts/really-big-elephants-postgresql-dw-15833438
Tables from multiple clusters can be collected and synchronized on one cluster using logical replication, and a single table can be broadcast to multiple clusters too.
4. Foreign Data Wrappers (Database Federation)

Foreign data wrappers (SQL MED) allow queries to read and write data to foreign data sources. Foreign database support includes:

- CouchDB
- Informix
- MongoDB
- MySQL
- Neo4j
- Oracle
- Postgres
- Redis

The transfer of joins, aggregates, and sorts to foreign servers is not yet implemented.

http://www.postgresql.org/docs/current/ddl-foreign-data.html
http://wiki.postgresql.org/wiki/Foreign_data_wrappers
Foreign Data Wrappers to Interfaces

- JDBC
- ODBC
- LDAP
Foreign Data Wrappers to Non-Traditional Data Sources

- Files
- HTTP
- AWS S3
- Twitter
CREATE SERVER postgres_fdw_test
FOREIGN DATA WRAPPER postgres_fdw
OPTIONS (host 'localhost', dbname 'fdw_test');

CREATE USER MAPPING FOR PUBLIC
SERVER postgres_fdw_test
OPTIONS (password '');

CREATE FOREIGN TABLE other_world (greeting TEXT)
SERVER postgres_fdw_test
OPTIONS (table_name 'world');

\det
List of foreign tables
Schema | Table | Server
--------|--------|-------------------
public | other_world | postgres_fdw_test

Foreign Postgres server name in red; foreign table name in blue
Read and Read/Write Data Sources

- Postgres
  - ora_tab
  - mon_tab
  - tw_tab

- MongoDB

- Oracle

- Twitter
5. Postgres Centrality

Postgres can rightly take a central place in the data center with its:

- Object-relation flexibility and extensibility
- NoSQL-like workloads
- Powerful data analytics capabilities
- Access to foreign data sources

No other database has all of these key components.
Postgres’s Central Role

- Extensions
- NoSQL
- Foreign Data Wrappers
- Data Warehouse
- ISN
- JSON
- PL/R
- Easy DDL
- Sharding
- Window Functions
- Data Partitioning
- Bitmap Scans
- PostGIS
- Oracle
- MongoDB
- Twitter
- Twitter Bitmap Scans