

1: WORKING WITH DATA

DATA SOURCES

- New Data** – created for the sole purpose of the current application. **Obtaining data:** add on-demand or bulk data entry.
- Pre-existing Data** – already exist prior to application being created. Need manipulate in order to integrate: 1. **Extraction:** need to recover or extract; 2. **Conversion:** convert to new format; 3. **Cleaning:** may contain erroneous or unnecessary info
- External Sources** – data providers, crowdsourcing. **Advantage:** come pre-cleaned and in a format easily consumed, save manpower and money, delegate expertise. **Limitation:** no control over quality and structure, may be incomplete, ambiguous, may be different from what we need.

SHARING DATA

- There are legal restriction the use of data.
- Reason to share open data:** commercial reason (drive sales); ethical reason (common good); contractual requirements (gov's budget); interoperability (postcode).
- Reason NOT to share open data:** restriction on source data; control of use; value of the data; data sensitivity; data privacy.
- Challenges:** Default legal positions on data use are complex (differing jurisdictions); Variations in copyright laws globally complicate data usage terms.
- Licensing Concepts:** Licenses (granting – what a licensee can do) and waivers (relinquish rights – remove infringement concerns) are key legal instrument.
- Common License Terms:** Attribution; copyleft and non-commerciality clauses

SHAPE OF DATA

- Programming Languages:** Data types (float, int, etc.); **Data Models:** Relations between different data; **Data Serialization:** Data formats used for transmission; **Exchange Protocol:** standardisation for information exchange, i.e. unix socket, named pipes; **User Interfaces:** for humans to consume.
- Table:** structured representation of data where info is organised into rows (entities) and columns (attributes). **Strengths:** straightforward, easy to understand, suitable for structured data, efficient searching. **Weaknesses:** not suitable for hierarchical data.
- Tree:** based on metaphor of a real tree. **Strengths:** suitable for hierarchical data, can span levels deep. **Weaknesses:** each node can only have single parent.
- Graph:** nodes can have multiple parents. **Strengths:** flexible than a tree. **Weaknesses:** inefficient for searching in some cases
- Blobs, Media, Complex Data:** raw data representation without perceivable structure, i.e. raw audio file; use to extracted features instead of structured fields

OPEN DATA

- generally means: **Cost-free access**; **Barrier-free access** (findable); **Barrier-free use** (accessible); **Restriction-free use** (reusable).

FAIR DATA

- Findable, Accessible, Interoperable, Reusable.

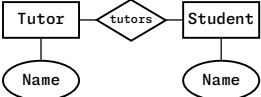
2: RELATIONAL DATABASES

- A Relational Database implements the **Relational Model**; but not necessarily true. Relation \approx Table, is a definition of a table and all the values stored in it.
- The set of rules – **Everything is a Relation:** all operations use the relational model; (data is represented and accessed as relations; table and database structure is accessed and altered as relations; It should be **robust abstracted system**, unaffected by: hardware changes; operating system changes; disk replacement; distributed data
- Relational Model \neq SQL \neq RDBMS implementation:** Relational Model is *not the same* as Entity-Relationship Model; ER Model helps us model concepts, as part of the design of a Relational Database; SQL is *a portion of* the Relational Model.

THE ENTITY-RELATIONSHIP MODEL

- Is a abstract model, not necessary tied to relational database, can be used for other implementation (programming object model).

Entity: is the thing we want to model, must be uniquely identifiable and may have attributes. **Relationship:** is a connection or dependency between two Entities.



SQL

commands for manipulating structures **CREATE, DROP, TRUNCATE, ALTER**, or manipulating data **INSERT, SELECT, UPDATE, DELETE** or retrieve information **SELECT**

CREATE TABLE Planets (ID INT AUTO INCREMENT, PlanetName CHAR(8), DayLength INT, YearLength INT, PRIMARY KEY (PlanetName));

UPDATE Planet SET YearLength = 24 WHERE PlanetName = "Mars";

SELECT PlanetName FROM Planets WHERE DayLength > 200;

SELECT Planet.Name, Moon.Name FROM Planet INNER JOIN Moon ON Planet.Name=Moon.HasPlanet WHERE Planet.DayLength < 11;

JOINS

- Cross Join** (Cartesian Join): **[SELECT * FROM A, B]** joins all - expensive \rightarrow combining each row of first table with each row of second table; total rows is product of all entries in all tables $a \cdot b \cdot c \dots$
- Inner Join** **[SELECT * FROM A INNER JOIN B ON A.id = B.id]** only combine with matching values
- Left Join** **[SELECT * FROM A LEFT JOIN B ON A.id = B.id]** all records on left and matching values on right (right may be empty)
- Right Join** **[SELECT * FROM A RIGHT JOIN B ON A.id = B.id]** the opposite of Left Join.

CARDINALITY

- refers to how many rows in each of the table participate in a join match with how many rows in other table.
- 1:n** – one row in A joins with zero or more in B, i.e B with a FK referencing a PK in A.
- 1:1** – one row in A with exact one row in B, i.e. a table with a PK
- m:n** – any number of rows in A joins with any number of rows in B, i.e. a pivot / link / junction table with PK (attributeA, attributeB).

DATABASE INTEGRITY

- Common Errors:** Typo; Missing, invalid, inconsistent, duplicated data; Referential integrity error (delete a planet but not its moon).
- Join fields must match** – use FK, subsequent **INSERT** with wrong value will fail.
- Validity check** – use **CHECK** column constraint.
- Uniqueness** (Consistency) – use PK to guarantee uniqueness.
- Computed Values** (Consistency) – don't store them, i.e. count, sum, product
- Change should not cause inconsistency** – use FK rules, i.e. **ON DELETE CASCADE**.
- Table values should be inconsistent – remove **functional dependencies**.

NORMALISATION

- Non-loss decomposition:** is the decomposition of a single relationship into two or more relations, such that a join on the separate relations reconstructs the original.
- Example** – If $X = (P, Q)$ decomposes into $X1 = (P, Q)$ and $X2 = (Q, W)$, where Q is a common attribute and is unique, thus non-loss (lossless) join is possible.
- Functional Dependency (FD):** the value of one attribute (determinant) determines the value of another attribute (dependent), i.e. $ID \rightarrow X$, $ID \rightarrow Y$. (If we know ID, we also know X and Y, hence ID).

Partial Dependency (PD): If $ID \rightarrow (X, Y, Z)$ but $X \rightarrow Y$ and not $ID \rightarrow Y$, then it is PD.

Transitive Dependency (TD): Indirect relationship. Given FD Book \rightarrow Author Country, but Book \rightarrow Author and does not Author \rightarrow Book. Since Author \rightarrow Author Country, hence Book \rightarrow Author Country is TD.

Candidate Key: attribute that uniquely identifies a row in a relation, could be a combination of (non-redundant) attributes, whilst each non-key attribute is functionally dependent on every candidate key.

Normal forms – a set of rules to minimise anomalies, allow for insertion, deletion and update without causing data inconsistencies.

- 1NF:** All the attribute are single-valued (atomic) (no array); have unique names; and order in which data is stored does not matter.
- 2NF:** Every non-key attribute is fully dependent on the primary key; does not have partial dependency.
- 3NF:** Does not have any transitive dependency.
- Boyce and Codd Normal Form (BCNF):** For all $X \rightarrow Y$, X is a super key.
- 4NF:** No multi-valued dependency (exist multiple of same ID in a table).

ATOMIC, CONSISTENCY, ISOLATION, DURABILITY (ACID)

- Atomicity** (rollback): guarantees an operation that only make sense as a group, either fully completed or nothing happens.
- Consistency:** guarantees never in inconsistent state, when a group operation is being executed, other operations not allowed to access or modify that will lead to inconsistency.
- Isolation:** guarantees concurrent transactions leave the database in the same state as if they were executed sequentially.
- Durability:** guarantees once a transaction is committed, it remains committed in event of failure.
- Transaction:** mechanism for treating group operation as a block **BEGIN TRANSACTION, COMMIT**; In cases of error, it can be **ROLLBACK**; that undo the inconsistent state.

Malice and Accidental Damage

- SQL Injection:** adding malicious code into normal operation.
- Privilege Escalation:** malicious agent gaining direct access to the database.
- User Error:** intends to do one thing but does something else entirely.
- Non-confidential Data Sharing:** being shared inappropriately.

- Security and User Policies with SQL
- Fine-grained controls – user level, database level, table level and data.
- Grant access: **GRANT <COMMAND> || ALL > ON <RESOURCE> TO <USER / ROLE> WITH GRANT OPTION;**
- Revoke Access: **REVOKE <COMMAND> || ALL > ON <RESOURCE> TO <USER / ROLE>;**
- Create Role: **CREATE ROLE <Name>;**
- Delete Role: **DROP ROLE <Name>;**
- Assign Role: **GRANT <RoleName> TO <USER>;**

SQL FUNCTIONS

SUM, AVG, STD, VARIANCE, MAX, MIN, COUNT, COUNT(DISTINCT <col>), GROUP_CONCAT(<col1>, <col2>, ...)

QUERY EFFICIENCY

- Expensive in DB: **Searching** (checking value on every entry), **Sorting** (ordering data), **Copying** (reading and writing).
- If data is sorted – **using sorted table:** can use binary search (clustered indexing), use no extra space, $O(\log n)$ – but can only use one column to be primary key.
- Using indexes: **B-tree** or **Hash table** – keeps in memory, rather than disk.
- B-tree** – uses the concept of Binary Search Tree.
- Hash table** – can't support range searching or approximate searching.

Denormalisation – joins can be expensive, trades off integrity checks and reduce storage requirements.

Create a View – create virtual table (i.e. pre-joined) that can query data.

DISTRIBUTED DATABASES

- Reason why** – parallelisation, no single point of failure, dividing large dataset (into divided chunk that can be processed locally)
- Requirements for DD: Local Autonomy** (sites operate independently); **No Centralisation** (no single site controls transactions or operations); **Continuous Operation** (available most of time and reliable); **Location Independence** (user doesn't need to know where data is located); **Partition Independence** (user doesn't need to know how data is partitioned); Replication Independence (user doesn't need to be aware replication is used); **Distributed Queries** (query is sent to closest location); **DBMS Independence** (distribute data over different DBMS system)
- Partitioning** – **Vertical Partitioning** (divide by columns); **Horizontal Partitioning** (divide by rows).
- Catalogue Management** – information of the data being distributed
- Recovery Control** – usually **two-phase protocol** (every node is locked for the duration, completes its operations, only confirms when every nodes is happy), where there's one site acts as coordinator in any given transaction.

- Brewer's Conjecture** – three goals in tension (conflicting with each other, can't fully satisfy all at once): **Consistency** – all parts should converge on consistent state; **Availability** – every request should result in response eventually; **Partition Tolerance** – a network flaw breaks the network into separate subnets, the database should run and recover.

ALTERNATIVE DISTRIBUTED DATABASE

- If distributing databases is complex, why not simplify data structure.
- Key-Value Databases:** have two columns – key and value. 1. Easy parallel processing; 2. Easy partition; 3. Partition is always horizontal; 4. Processing must happen near the table where possible.
- MapReduce:** algorithm for processing key-value datasets, consist of **map procedure** (filtering and sorting) and a **reduce procedure** (summary operation), hence MapReduce.
- Map Phase** – with direct access to database, loops over all data, outputs a new key-value set. (extract large data to chunks of data, i.e. map(word, value) outputs key "word", value "1")
- Reduce Phase** – carried out by reducer workers, summarise the data based on a key. (performs further reduction on mapped chunks of data based on key, i.e. reduce(word, values) adds all values "count" for key "word")

DOCUMENT DATABASE;

ALTERNATIVE TO DD

- Document Databases:** middle ground between key-value and relational databases.
- Less strict:** can be nested; can be repeated; can be **order-sensitive**. Follows a tree structure.
- less interlinking:** or less important for data retrieval, (a trade off for the flexibility)
- Formats:** Markup languages for text; Markup languages for other data; Bespoke formats; JSON.
- MongoDB** is one implementation of such, capable of distributing by means of sharding (horizontal partitions of data).

MONGO DB "SQL"

```
// INSERT
db.col.insertOne(data);
db.col.insertMany([...])
// READ
db.movies.findOne({year: 2015});
db.movies.find({title: /Man*/})
// UPDATE
db.movies.updateOne({title: "ABC"},
{$set: {year: 2015}});
db.movies.updateMany({actors: "Elle
"}, {"actors.$": "Ele"})
```

3: SEMANTIC DATABASES

- share more meanings on the data – specifications about the data and syntax on how to validate.
- Machine-readable Semantics:** enabling computer systems to interpret data and make inferences based on shared semantics.
- Deductive Databases:** rules and logics to deduce new information from existing data.
- Semantic web:** is a domain that focuses on enhancing the meaning and interoperability of data on the internet.
- Levels of sharing data:** 1. Sharing Documents (carry semantics); 2. Formal Specifications (in computer readable form); 3. Human-readable Definitions.

EXTENSIBLE MARKUP LANGUAGE (XML)

- let us define and store data in a shareable manner, has tree structure.
- Well-formed XML:** adheres to the basic syntactic rule of XML.
- Valid XML:** whether it conforms to a specific XML schema or Document Type Definition (DTD)
- XML vs RDBMS:** XML gives a different; looser structure, harder to index; supports richer searching (and indexing), usually parallelisable; can be shared directly; can be targeted by web links.

TRANSFORMING XML "QUERYING"

- allow to transform XML into another XML or other formats
- Two primary languages:** 1. eXtensible Stylesheet Language Transformation (XSLT); 2. XQuery.
- XSLT:** works like templating.

```
<xsl:template match="element">
<table>
<xsl:apply-templates select="*"
/>
</table>
<xsl:template>
<xsl:template match="child">
<tr>
<xsl:apply-templates select="."
/>
</tr>
</xsl:template>
<xsl:template match="nestedChild">
<td>
<xsl:value-of select="nestedElement">
<td>
</xsl:template>
Alternative:
<xsl:template match="element">
<table>
<xsl:for-each select="child">
<tr>
<td><xsl:value-of select="nestedChild">
<td>
</xsl>
</table>
</xsl:template>
```

```
<xquery> intended to be SQL-like, simpler syntax - FLWOR: F for clause, L let clause, W where clause, O order by clause, R return clause.
<table>
{
let $doc := doc("some.xml")
for $child in $doc/elementA
where $doc/price > 30
order by $doc/title
return
<tr>
<td>{$child/nestedElement/text()}</td>
<td>{$child/../elementB/text()}</td>
</tr>
}
</table>
```

XML SCHEMA

- Document Type Definition (DTD):** oldest one, inherited from SGML, limited.
- in document,**

```
<?xml version="1.0"?>
<!DOCTYPE authors SYSTEM "http://...
.library.dtd">
```
- in schema document,**

```
<!ELEMENT authors (author)+> -- al
low one or many
```
- XML Schema Definition (XSD):** recommended by W3C for formally describe elements.
- in document,**

```
<authors xmlns="http://..." xml:id=
"authors.xsd">
</authors>
```
- in schema document,**

```
<xs:element name="authors">
<xs:complexType>
<xs:element ref="author" minOccurs="1"
maxOccurs="unbounded" />
</xs:complexType>
</xs:element>
```
- ```
<xs:element name="author" type="xs:
string" />
```

```
<in schema document,
<xs:element name="authors">
<xs:complexType>
<xs:element ref="author" minOccurs="1"
maxOccurs="unbounded" />
</xs:complexType>
</xs:element>
```

```
RELAX NG: RRegular Language for XML
Next-Gen specifies a pattern for the structure
and content, whether in XML (below) or other
syntax.
<element name="authors">
<oneOrMore>
<element name="author">
<text />
</element>
<oneOrMore>
</element>
```

```
Schematron: structural schema language
written in XML using elements and XPath,
generally used as integrity checks and
combine with another schema.
<rule context="/date">
<assert test="date < 1; current-date()>
Invalid date
</assert>
</rule>
```

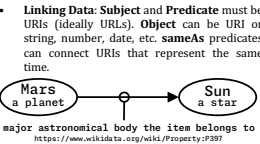
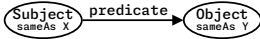
**One Document Does it all (ODD):** superset language that generates all the different languages – DTD, XSD, etc. **Text Encoding Initiative (TEI)** develops an ODD.

- Schema defines** – which elements are used, what can they contain, what data is passed, what order, what attributes are used, what structures are equivalent, what structure is mutually exclusive.
- They are used to **encode** structures (create, validate encodings (debug or enforce integrity), **support** programming with documents (auto-generate class definitions) or machine reasoning (computer deduce meaning).

## 4: LINKED DATA & SEMANTIC WEB

- Web Links:** Links are one-way, no permission needed, no central registry of links.
- Uniform Resource Locator (URL) / Uniform Resource Identifier (URI):** Guarantees unique, responsibility of maintenance (has domain name owner), unlimited number of URLs, unique ID independent of server.
- Remote Description Framework (RDF):** a model representation of linked data on the web based on triples.
- URLs are key to solving challenges – maintaining keys on the web; finding data on the web; sharing meaning; sharing entities.

### REMOTE DESCRIPTION FRAMEWORK (RDF)



- Dereferencing OK** – URLs can just be ID – don't need to resolve; **Better:** Give data about the URI; **Best:** Content negotiation (human readable in browsers, linked data for machines)
- Serialisations:**
- n-triples** (simple): list the triples
- Subject URI** < Predicate URI > Object URI.

```
et:Deimos a et:Moon; dt:satelliteOf et:Mars .
PREFIX et: <http://.../entity>
PREFIX dt: <http://.../direct>
```

```
<div vocab="http://schema.org/" type="Person">

Manu Sporny
Founder
<div>
E-mail: msporny@digitalbazaar.com
</div>
</div>
```

```
JSON-LD: add-on to JS, not exactly a
serialisation, graph data
{
"eid": "https://...Deimos"
"type": "https://...Moon"
"https://...satelliteOf": {
"eid": "https://...Mars"
"type": "https://...Planet"
}
}
```

**XML/RDF** (Painful): one of the earliest, XML-based serialisation, ugly to read, trying to put tree structure into graph structure (avoid this)

### RDF SCHEMA (WEB ONTOLOGIES)

- Web Ontology Language (OWL):** allow us to encode the logic of the system.
- Designing an ontology: 1. use existing ontologies where possible; 2. combine effort with others; 3. test with real data; 4. don't get lost in rabbit holes (avoid adding unnecessary details); 5. don't be wrong; 6. designing good ontologies takes times; 6. multiple viewpoints are vital; 7. drawing helps; 8. be as explicit as possible to draw out problems; 9. try out protege for ontology specification

### RDF QUERY LANGUAGE

- hard to search efficiently, partly because no registry of information.
- Triplestore:** one type of graph database, uses RDF to cache a chunk of semantic web.
- SPARQL:** SPARQL Protocol and RDF Query Language
- PREFIX foaf:** <http://...foaf/0.1>
- PREFIX ex:** <http://...>
- SELECT ?friend** WHERE { ex:Alice foaf:knows ?friend . }

If we want to know name of person, **SELECT ?Name** WHERE { ex:Alice foaf:knows ?friend . }

```
?friend foaf:name ?fName .
}
SELECT ?fName
WHERE {
ex:Alice foaf:knows+ ?friend .
?friend foaf:name ?fName .
}
LIMIT 20
```

If we want unique list instead, **SELECT DISTINCT ?fName** WHERE { ex:Alice foaf:knows+ ?friend . ?friend foaf:name ?fName . } **LIMIT 20**

## 5: MULTIMEDIA & INFORMATION RETRIEVAL

- Core ideas:** User has an information need; A need is expressed as a query; Query is executed over data by Information Retrieval system.
- Feature:** based on searching the document, but using features; high-level structures created from raw data to extract meaningful information, i.e. metadata. **Reasons:** helps to move from low-level signal to high-level concepts, reduce complex data to simpler data, define expectation of salience, re-weighted based on task or user. **Challenges:** bridging the "semantic gap" between user information needs and low-level data.
- Types of Features:** tokens (text), zero-crossing (audio), pitch estimation (audio), color regions (image), loudness (audio).
- Feature Space:** multi-dimensional space where each dimension represents a specific feature.
- Similarity in Feature Space:** distance metrics can be used – **Euclidean Distance** (shortest distance), **Manhattan Distance** (summing the absolute difference in each dimension), **Identity of Indiscernibles** (identical points 0 distance), **Symmetry**  $d(a,b) = d(b,a)$ , **Triangular Inequality**  $d(a,c) \leq d(a,b) + d(b,c)$ .
- Speed & Indexing:** Speed in IR is important.
- Speed:** Precompute feature are indices; Many searches are parallelisable (mapReduce); reduce dimensions – can increase speed and reduce irrelevant results.
- Search:** Spatial indexes of metric spaces can be very fast for retrieval; R-trees ( $O(\log n)$  retrieval; built in to some RDBMS packages.
- Measure Success:**
- AT:** Actual Total in whole collection, including those haven't been classified;  $AT = TP + FP$
- TR (Total):** Total Retrieved (the resulting sample size that was retrieved);  $TR = TP + FP$
- TP:** True Positives (correctly identified that attribute is absent);  $TP = TR \cdot Precision$  or  $TR - TP$
- TN:** True Negatives (correctly identified that attribute is absent);  $TN = TR - (TP + FP + FN)$
- FP:** False Positives (correctly identified that attribute is present);  $FP = (TP / Precision) - TP$  or  $TR - TP$
- FN:** False Negatives (incorrectly classified that attribute is absent);  $FN = (TP / Recall) - TP$  or  $AT - TP$
- Precision:** proportion of positive results that are true positives, with few irrelevant (false positives) entries. (user looks for a match)  $TP / (TP + FP)$
- Recall:** proportion of how many relevant results retrieved, with few (false negatives) not appearing in result set. (user looks for all matches)  $TP / (TP + FN)$
- F-measure:** a combined measure that balance precision and recall. (user looks for some matches)  $(2 * Precision * Recall) / (Precision + Recall)$