Normalization

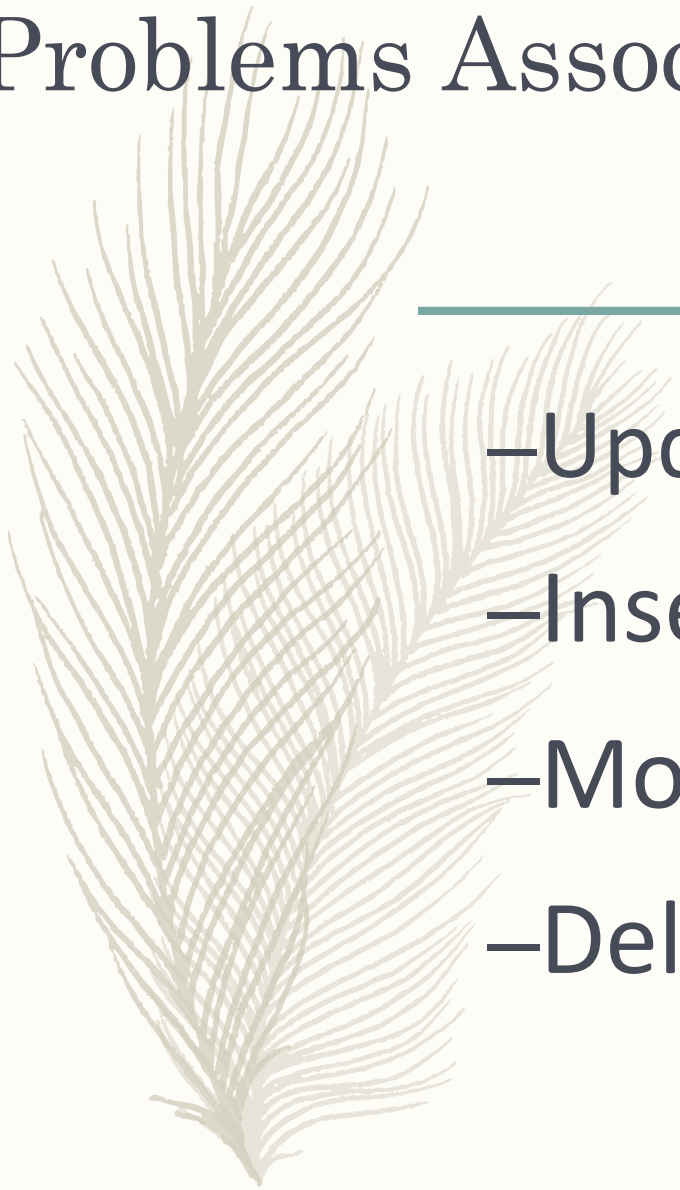
What is a good database design?

- A database design in which all the user requirements are satisfied
- One that does not waste storage space
- One that does not lead to misinformation, loss of information or inconsistent information

Redundancy

- Unnecessary repetition of information in the database is called redundancy.
- Redundancy results in several problems, wastage of space is just one of them.

Problems Associated with Redundancy



- Update anomalies
- Insertion anomalies
- Modification anomalies
- Deletion anomalies

Sample Table (DeptEmp)

Emp#	**Ename**	**Salary**	**Dept#**	**Dname**	**Dloc**
101	aaa	10000	2	Acc	HQ
102	bbb	7000	1	Stores	Plant
103	ccc	12000	2	Acc	HQ
104	ddd	9000	3	HR	HQ

The Database After Normalization

Emp

Emp#	**Ename**	**Salary**	**Dept#**
101	aaa	10000	2
102	bbb	7000	1
103	ccc	12000	2
104	ddd	9000	3

Dept

Dept#	**Dname**	**Dloc**
1	Stores	Plant
2	Acc	HQ
3	HR	HQ

Wrong Database Design

Emp

Emp#	Ename	Salary
101	aaa	10000
102	bbb	7000
103	ccc	12000
104	ddd	9000

Dept

Dept#	Dname	Dloc
1	Stores	Plant
2	Acc	HQ
3	HR	HQ

Join

- We decompose a table into multiple tables to avoid redundancy and associated problems.
- However, Sometimes we need to put together information from multiple tables.
- For that, we perform a join operation.

The Basis for Performing a Join

- Join is always performed based on some column(s) common between the two tables.
- These column(s) always form primary key – foreign key relationship between the two tables, i.e. they are primary/unique key in one table and foreign key in the other.

The Example Database

Emp

Emp#	Ename	Salary	Dept#
101	aaa	10000	2
102	bbb	7000	1
103	ccc	12000	2
104	ddd	9000	3

Dept

Dept#	Dname	Dloc
1	Stores	Plant
2	Acc	HQ
3	HR	HQ

The Link Between the Tables

- The column “Dept#” is common between the tables.
- It is the primary key in the Dept table and foreign key in the Emp table.
- It is the link between the two tables.

How Will the Two Tables be Joined?

- The rows from the Emp table will be taken one-by-one and the Dept# column in it will be examined.
- The row containing the same value in the Dept# column of the Dept table will be joined with the corresponding row in the Emp table.

The Result of Joining the Two Tables

Emp

Emp#	Ename	Salary	Dept#	Dept#	Dname	Dloc
101	aaa	10000	2	2	Acc	HQ
102	bbb	7000	1	1	Stores	Plant
103	ccc	12000	2	2	Acc	HQ
104	ddd	9000	3	3	HR	HQ

Dept

Dept#	Dname	Dloc
1	Stores	Plant
2	Acc	HQ
3	HR	HQ

Information Loss

- Sometimes, if the tables are improperly decomposed, spurious rows are generated in the result of the join.
- Even though the gross quantity of data increases, there is actually information loss.

The Example of Information Loss

Emp

Emp#	Ename	Salary	Dloc
101	aaa	10000	HQ
102	bbb	7000	Plant
103	ccc	12000	HQ
104	ddd	9000	HQ

Dept

Dept#	Dname	Dloc
1	Stores	Plant
2	Acc	HQ
3	HR	HQ

Result of Joining

Joined Table

Emp#	Ename	Salary	Dloc	Dept#	Dname	Dloc
101	aaa	10000	HQ	2	Acc	HQ
101	aaa	10000	HQ	3	HR	HQ
102	bbb	7000	Plant	1	Stores	Plant
103	ccc	12000	HQ	2	Acc	HQ
103	ccc	12000	HQ	3	HR	HQ
104	ddd	9000	HQ	2	Acc	HQ
104	ddd	9000	HQ	3	HR	HQ

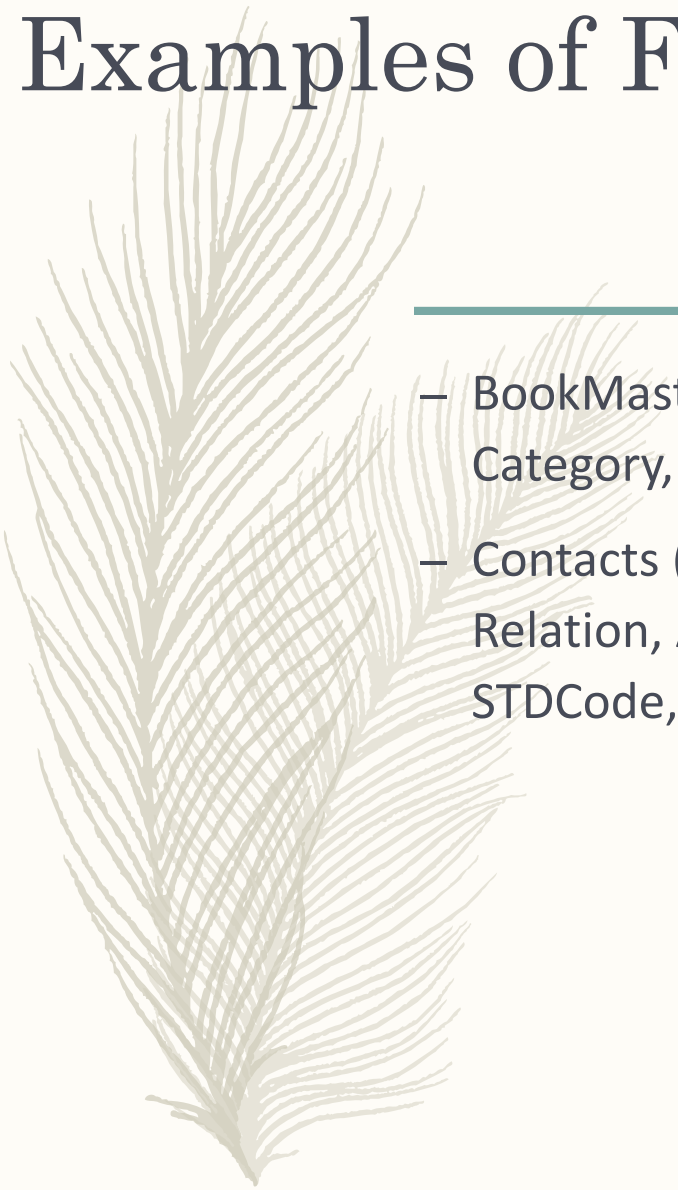
Lossless Join

- Lossless join means a table, when decomposition is necessary, must be decomposed in such a way that if we join the decomposed table back, we always get the original table.
- Lossless join is an important requirement in database design.

Functional Dependencies

- If the values in an attribute-set A can always be determined (derived) from the values in another attribute-set X, then A is said to be functionally dependent on X and the functional dependency is written as X → A.

Examples of Functional Dependencies



- BookMaster (Book#, Title, Authors, Edition, Publisher, Category, ISBN#)
- Contacts (ContactId, Name, Sex, BirthDate, Category, Relation, Addr1, Addr2, Addr3, City, PIN, State, Country, STDCode, Phones, Mobile, SpouseName, SpouseBirthDate)

Types of Normalization

- 1NF (1st Normal Form)
- 2NF (2nd Normal Form)
- 3NF (3rd Normal Form)
- BCNF (Boyce-Codd Normal Form)
- 4NF (4th Normal Form)
- 5NF (5th Normal Form) aka PJNF (Project-Join Normal Form)
- DKNF (Domain-Key Normal Form)

The First Normal Form (1NF)

- All values in the cells should be atomic (i.e. indivisible).
- Multivalued attributes are not allowed.
- Composite attributes are not allowed.
- No “tables within tables” (nested relations).

The Supplier Example

Sup#	**SName**	**Items**		
1	A Ltd.	**Item#**	**IName**	**Price**
		101	aaa	100
		102	bbb	200
		103	ccc	300
2	B Ltd.	**Item#**	**IName**	**Price**
		104	ddd	150
		101	aaa	100

The Supplier Example

Sup#	SName
1	A Ltd.
2	B Ltd.

Item#	IName	Price
101	aaa	100
102	bbb	200
103	ccc	300
104	ddd	150

Sup#	Item#
1	101
1	102
1	103
2	104
2	101

Partial Functional Dependency

- If (x, y) → z and also y → z then z is said to be partially dependent on (x, y).

Example:

- (UserRegNo, PhoneNo,Gender)
- Gender is partially dependent on UserRegNo (not on PhoneNo).

Full Functional Dependency

- If (x, y) → z and neither x → z nor y → z then z is said to be fully dependent on (x, y).

Example:

- (EmpID, ProjectID,Hours)
- Hours is fully FD on EmpID and ProjectID.

The Second Normal Form (2NF)

- No non-key attribute should be dependent on a part of a key
- All non-key attributes should be fully functionally dependent on the key(s)
- Partial dependencies are not allowed

Example of 2NF Violation & Solution

- SupplierAccounts (Sup#, Sname, Item#, Iname, Price)
- The Solution:

  Supplier (Sup#, Sname)

  Item (Item#, Iname,Price)

  SupItem (Sup#, Item#)

Transitive Dependency

- A functional dependency is said to be transitive if it is indirectly formed by two functional dependencies.
- X -> Z is a transitive dependency if the following three functional dependencies hold true:
  1. X->Y
  2. Y does not ->X
  3. Y->Z

Example of Transitive Dependency

Example:

- {Book} ->{Author} (if we know the book, we knows the author name)
- {Author} does not ->{Book}
- {Author} -> {Author_nationality}

The Third Normal Form (3NF)…

- 2NF should be satisfied.
- No non-key attribute should be dependent on another non-key attribute.
- No non-key attribute should be transitively dependent on the key.

…The Third Normal Form (3NF)

- All non-key attributes should be fully functionally dependent on the key and key only.
- If X→A is a functional dependency, then either X should be a super key or A should be a key attribute.

Example of 3NF Violation & Solution

- AccountMaster (AcType, Ac#, Cust#, CustName, Balance)

- The Solution:

  AccountMaster (AcType, Ac#, Cust#, Balance)

  CustomerMaster (Cust#, CustName)

The Boyce-Codd Normal Form (BCNF)…

- 3NF should be satisfied
- No (key or non-key) attribute should be dependent on another non-key attribute.
- No (key or non-key) attribute should be transitively dependent on the key

…The Boyce-Codd Normal Form (BCNF)

- All (key and non-key) attributes should be fully functionally dependent on the key and key only.
- If X→A is a functional dependency, then X must be a super key

Example of BCNF…

- Consider a University.
- One teacher can teach one subject only.
- A subject may be taught by one or more teachers.
- A student can take one or more subjects.

…Example of BCNF…

- UniInfo (Teacher, Subject, Student)
- The Dependencies:

  Teacher → Subject

  (Subject, Student) → Teacher
- The key: (Subject, Student)

…Example of BCNF…

- Satisfies 3NF
- Does not satisfy BCNF
- The Solution:

  TeacherSubject (Teacher, Subject)

  TeacherStudent (Teacher, Student)

Dependency Preservation

- Dependency preservation means each functional dependency in a database design should be testable using one table only.
- All the attributes involved in a functional dependency should be part of the same table.

BCNF and Dependency Preservation

- It is not always possible to produce a design that satisfies dependency preservation as well as BCNF.
- Our previous solution that was in BCNF does not satisfy dependency preservation.

3NF and Dependency Preservation

- It can be proved that it is always possible to produce a design that satisfies dependency preservation as well as 3NF.
- Our previous example, before decomposition, satisfied dependency preservation.

Important Goals in Normalization

- To achieve the highest normal form
- Lossless join (Compulsory)
- Dependency preservation (optional)

Codd's Rules

Introduction

- According to Elmasri and Navathe (1994), Dr. E. F. Codd, the originator of the relational data model, published a two-part article in *Computer World* (Codd, 1985) that lists 12 rules for how to determine whether a DBMS is relational and to what extent it is relational.
- These rules provide a very useful yardstick for evaluating a relational system.

Rule 0

- The system must **qualify as *relational***, as a *database*, and as a *management system*.
- For a system to qualify as a relational database management system (RDBMS), that system must use its *relational* facilities (exclusively) to *manage* the *database*.

Rule 1: The *information rule*

- All information in the database is to be **represented in one and only one way**, namely by values in column positions within rows of tables.

Rule 2: The *guaranteed access rule*

- All **data must be accessible**. This rule is essentially a restatement of the fundamental requirement for primary keys. It says that every individual scalar value in the database must be logically addressable by specifying the name of the containing table, the name of the containing column and the primary key value of the containing row

Rule 3: *Systematic treatment of null values*

– The DBMS **must allow each field to remain null (or empty).** Specifically, it must support a representation of "missing information and inapplicable information" that is systematic, distinct from all regular values (for example, "distinct from zero or any other number", in the case of numeric values), and independent of data type. It is also implied that such representations must be manipulated by the DBMS in a systematic way

Rule 4:
Active online catalog based on the relational model

- The system must support an **online, inline, relational catalog** that is accessible to authorized users by means of their regular query language.
- That is, users must be able to access the **database's structure (catalog)** using the same query language that they use to access the database's data

Rule 5: The *comprehensive data sublanguage rule*

- The system **must support at least one relational language that**
  - Has a linear syntax
  - Can be used both interactively and within application programs,
  - Supports data definition operations (including view definitions), data manipulation operations (update as well as retrieval), security and integrity constraints, and transaction management operations (begin, commit, and rollback).

Rule 6: The *view updating rule*

- All views that are theoretically updatable must be updatable by the system.

Rule 7: *High-level insert, update, and delete*

- The system **must support set-at-a-time *insert*, *update*, and *delete* operators.**
- This means that data can be retrieved from a relational database in sets constructed of data from multiple rows and/or multiple tables. This rule states that insert, update, and delete operations should be supported for any retrievable set rather than just for a single row in a single table

Rule 8:
Physical data independence

- Changes to the physical level (how the data is stored, whether in arrays or linked lists etc.) must not require a change to an application based on the structure

Rule 9:
Logical data independence

- Changes to the logical level (tables, columns, rows, and so on) must not require a change to an application based on the structure.
- Logical data independence is more difficult to achieve than physical data independence

Rule 10: *Integrity independence*

- **Integrity constraints** must be specified separately from application programs and **stored in the catalog**.
- It must be possible to change such constraints as and when appropriate without unnecessarily affecting existing applications

Rule 11: *Distribution independence*

- The distribution of portions of the database to various locations should be invisible to users of the database. Existing applications should continue to operate successfully:
  - when a distributed version of the DBMS is first introduced; and
  - when existing distributed data are redistributed around the system.

Rule 12: The *nonsubversion rule*

- If the system provides a low-level (record-at-a-time) interface, then that interface cannot be used to subvert the system, for example, bypassing a relational security or integrity constraint