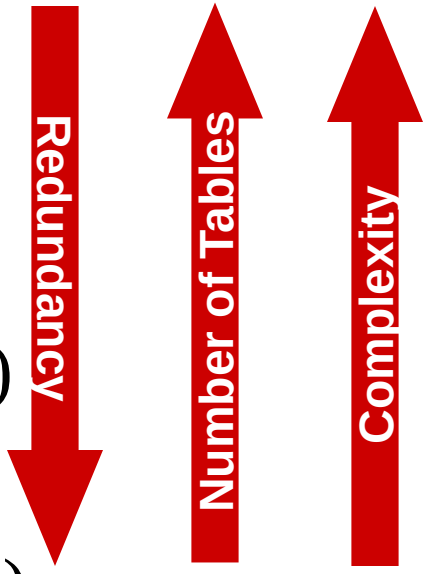
# Normalization

- An analytical technique used during logical database design
- This is the process which allows you to winnow out redundant data within your database.
- This involves restructuring the tables to avoid data inconsistencies (**insert/update/delete anomalies**)
- A properly normalized database should have the following characteristics
  - Scalar values in each fields
  - Absence of redundancy.
  - Minimal/No loss of information
  - Minimal Uses of NULL values

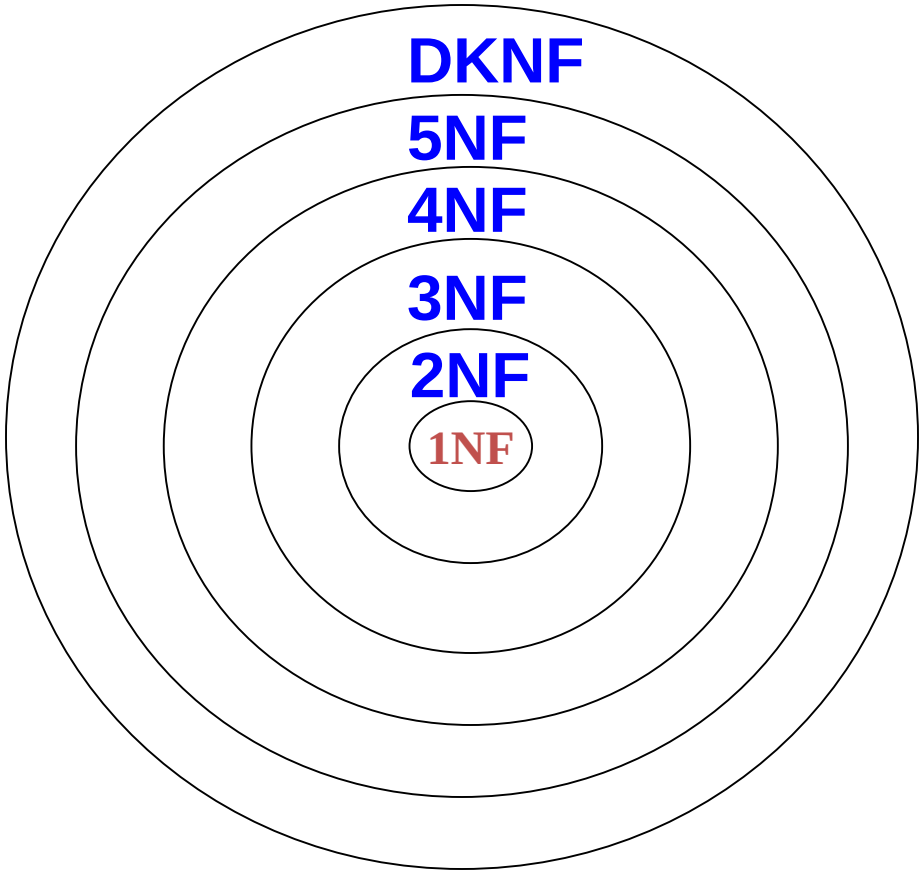
# Levels of Normalization

- Levels of normalization based on the amount of redundancy in the database.
- Various levels of normalization are:
  - First Normal Form (1NF)
  - Second Normal Form (2NF)
  - Third Normal Form (3NF)
  - Boyce-Codd Normal Form (BCNF)
  - 4NF & 5 NF
  - Domain Key Normal Form (DKNF)




- Most databases should be in 3NF or BCNF in order to avoid the database anomalies.

# Levels of Normalization




Each lower level is a subset of the higher level

# Data Anomalies

- INSERT Anomaly
- UPDATE Anomaly
- DELETE Anomaly

| Roll No | CourseID | Student Name | Address | CourseName |
|---|---|---|---|---|
| S001 | C1 | Aditya | Jaipur | Java |
| S001 | C2 | Aditya | Jaipur | Database |
| S002 | C2 | Omkar | Mumbai | Database |
| S003 | C1 | Shilpa | Pune | Java |
| S004 | C3 | Shweta | Pune | OS |

# First Normal Form (1NF)

A table is considered to be in 1NF if all the fields contain only scalar values (as opposed to list of values).

**Example (Not 1NF)**

| ISBN | Title | AuName | AuPhone | PubName | PubPhone | Price |
|---|---|---|---|---|---|---|
| 0-321-32132-1 | Core Java | Sleepy, Snoopy, Grumpy | 321-321-1111, 232-234-1234, 665-235-6532 | Small House | 714-000-0000 | $34.00 |
| 0-55-123456-9 | Postgres | Jones, Smith | 123-333-3333, 654-223-3455 | Small House | 714-000-0000 | $22.95 |
| 0-123-45678-0 | Oracle | Joyce | 666-666-6666 | Alpha Press | 999-999-9999 | $34.00 |
| 1-22-233700-0 | MongoDB | Roman | 444-444-4444 | Big House | 123-456-7890 | $25.00 |

**Author and AuPhone columns are not scalar**

# 1NF - Decomposition

1. Place all items that appear in the repeating group in a new table
2. In the new table add the primary key column of the table from which the repeating group was extracted.

**Example (1NF)**

| ISBN | Title | PubName | PubPhone | Price |
|---|---|---|---|---|
| 0-321-32132-1 | Core Java | Small House | 714-000-0000 | $34.00 |
| 0-55-123456-9 | Postgres | Small House | 714-000-0000 | $22.95 |
| 0-123-45678-0 | Oracle | Alpha Press | 999-999-9999 | $34.00 |
| 1-22-233700-0 | MongoDB | Big House | 123-456-7890 | $25.00 |

| ISBN | AuName | AuPhone |
|---|---|---|
| 0-321-32132-1 | Sleepy | 321-321-1111 |
| 0-321-32132-1 | Snoopy | 232-234-1234 |
| 0-321-32132-1 | Grumpy | 665-235-6532 |
| 0-55-123456-9 | Jones | 123-333-3333 |
| 0-55-123456-9 | Smith | 654-223-3455 |
| 0-123-45678-0 | Joyce | 666-666-6666 |
| 1-22-233700-0 | Roman | 444-444-4444 |

# Functional Dependencies

1. If one set of attributes in a table determines another set of attributes in the table, then the second set of attributes is said to be functionally dependent on the first set of attributes.

**Example 1**

| ISBN | Title | Price |
|---|---|---|
| 0-321-32132-1 | Core Java | $34.00 |
| 0-55-123456-9 | Postgres | $22.95 |
| 0-123-45678-0 | Oracle | $34.00 |
| 1-22-233700-0 | MongoDB | $25.00 |

Table Scheme: {ISBN, Title, Price}

Functional Dependencies: {ISBN} → {Title}

{ISBN} → {Price}

# Functional Dependencies

## Example 2

| PubID | PubName | PubPhone |
|---|---|---|
| 1 | Big House | 999-999-9999 |
| 2 | Small House | 123-456-7890 |
| 3 | Alpha Press | 111-111-1111 |

**Table Scheme: {PubID, PubName, PubPhone}**

**Functional Dependencies: {PubId} → {PubPhone}**

**{PubId} → {PubName}**

**{PubName, PubPhone} → {PubID}**

## Example 3

| AuID | AuName | AuPhone |
|---|---|---|
| 1 | Sleepy | 321-321-1111 |
| 2 | Snoopy | 232-234-1234 |
| 3 | Grumpy | 665-235-6532 |
| 4 | Jones | 123-333-3333 |
| 5 | Smith | 654-223-3455 |
| 6 | Joyce | 666-666-6666 |
| 7 | Roman | 444-444-4444 |

**Table Scheme: {AuID, AuName, AuPhone}**

**Functional Dependencies: {AuId} → {AuPhone}**

**{AuId} → {AuName}**

**{AuName, AuPhone} → {AuID}**

# Second Normal Form (2NF)

- For a table to be in 2NF, there are two requirements
  - The database is in first normal form
  - All **nonkey** attributes in the table must be functionally dependent on the **entire primary key**
- **Example 1 (Not 2NF)**
- **Scheme → {Title, PubId, AuId, Price, AuAddress}**

  **Key → {Title, PubId, AuId}**

  **{Title, PubId, AuID} → {Price}**

  **{AuID} → {AuAddress}**

  – **AuAddress does not belong to a key**

  – **AuAddress functionally depends on AuId which is a subset of a key**

# Second Normal Form (2NF)

**Example 2 (Not 2NF)**

Scheme → {City, Street, HouseNumber, HouseColor, CityPopulation}

- key → {City, Street, HouseNumber}
- {City, Street, HouseNumber} → {HouseColor}
- {City} → {CityPopulation}

– CityPopulation does not belong to any key.

– CityPopulation is functionally dependent on the City which is a subset of the key.

# 2NF - Decomposition

- If a data item is fully functionally dependent on only a part of the primary key, move that data item and that part of the primary key to a new table.
- If other data items are functionally dependent on the same part of the key, place them in the new table also
- Make the partial primary key copied from the original table the primary key for the new table. Place all items that appear in the repeating group in a new table
- **Example 1 (Convert to 2NF)**

  **Old Scheme → {Title, PubId, AuId, Price, AuAddress}**

  **New Scheme → {Title, PubId, AuId, Price}**

  **New Scheme → {AuId, AuAddress}**

# 2NF - Decomposition

**Example 2 (Convert to 2NF)**

**Old Scheme → {City, Street, HouseNumber, HouseColor, CityPopulation}**

**New Scheme → {City, Street, HouseNumber, HouseColor}**

**New Scheme → {City, CityPopulation}**

# Third Normal Form (3NF)

- This form dictates that all **non-key** attributes of a table must be functionally dependent on a key i.e. there can be **no interdependencies among non-key attributes**.
- For a table to be in 3NF, there are two requirements
  - The table should be second normal form
  - No attribute is **transitively dependent** on the primary key

# Third Normal Form (3NF)

**Example 1 (Not in 3NF)**

Scheme → {Studio, StudioCity, CityTemp}

- Key → {Studio}
- {Studio} → {StudioCity}
- {StudioCity} → {CityTemp}
- {Studio} → {CityTemp}

– Both StudioCity and CityTemp depend on the entire key hence 2NF

– **CityTemp** transitively depends on **Studio** hence violates 3NF

**Example 2 (Not in 3NF)**

Scheme → {BuildingID, Contractor, Fee}

- Key → {BuildingID}
- {BuildingID} → {Contractor}
- {Contractor} → {Fee}
- {BuildingID} → {Fee}

– Both Contractor and Fee depend on the entire key hence 2NF

– **Fee** transitively depends on the **BuildingID**

| BuildingID | Contractor | Fee $ |
|---|---|---|
| 100 | Shiva | 1200 |
| 150 | Akash | 1100 |
| 200 | Shiva | 1200 |
| 250 | Prithvi | 1000 |
| 300 | Shiva | 1200 |

# 3NF - Decomposition

- Move all items involved in transitive dependencies to a new entity.
- Identify a primary key for the new entity.
- Place the primary key for the new entity as a foreign key on the original entity.

# 3NF - Decomposition

## Example 1 (Convert to 3NF)

Old Scheme → {Studio, StudioCity, CityTemp}

New Scheme → {Studio, StudioCity}

New Scheme → {StudioCity, CityTemp}

## Example 2 (Convert to 3NF)

Old Scheme → {BuildingID, Contractor, Fee}

New Scheme → {BuildingID, Contractor}

New Scheme → {Contractor, Fee}

| BuildingID | Contractor |
|---|---|
| 100 | Shiva |
| 150 | Akash |
| 200 | Shiva |
| 250 | Prithvi |
| 300 | Shiva |

| Contractor | Fee |
|---|---|
| Shiva | 1200 |
| Akash | 1100 |
| Prithvi | 1000 |

# Boyce-Codd Normal Form (BCNF)

- BCNF does not allow dependencies between attributes that belong to candidate keys.
- BCNF is a refinement of the third normal form in which it drops the restriction of a non-key attribute from the 3rd normal form.

# Boyce-Codd Normal Form (BCNF)

**Example - Movie (Not in BCNF)**

Scheme → {MovieTitle, MovieID, ActorName, Payment }

- Key1 → {MovieTitle, ActorName}
- Key2 → {MovieID, ActorName}
- {MovieID} → {MovieTitle}
- Payment functionally depend on both Candidate Keys, thus 3NF
  - Dependency between MovieID & MovieTitle Violates BCNF

# BCNF - Decomposition

- Place the two candidate keys in separate entities
- Place each of the remaining data items in one of the resulting entities according to its dependency on the primary key.

# BCNF - Decomposition

**Example (Convert to BCNF)**

**Old Scheme** → {MovieTitle, MovieID, ActorName, Payment }

New Scheme → {MovieID, ActorName, Payment}

New Scheme → {MovieTitle, ActorName}

– Loss of dependency (FD) {MovieID} → {MovieTitle}

**New Scheme → {MovieID, ActorName, Payment}**

**New Scheme → {MovieID, MovieTitle}**

– We got the {MovieID} → {MovieTitle} dependency (FD) back

# Decomposition – Loss of Information

- If decomposition does not cause any loss of information it is called a **lossless** decomposition.
- If a decomposition does not cause any dependencies to be lost it is called a **dependency-preserving** decomposition.
- Any table scheme can be decomposed in a **lossless** way into a collection of smaller schemas that are in **BCNF** form. However the **dependency preservation is not guaranteed**.
- Any table can be decomposed in a **lossless** way into **3rd normal form** that **also preserves the dependencies**.
  - 3NF may be better than BCNF in some cases

# Fourth Normal Form (4NF)

- **Fourth normal form eliminates independent many-to-one relationships between columns.**
- **To be in Fourth Normal Form,**
  - **A relation must first be in Boyce-Codd Normal Form (BCNF).**
  - **A given relation may not contain more than one multi-valued attribute. i.e. there should be no multi-valued dependency (MVD).**
- **Example 1 (Not in 4NF)**
  - **Scheme → {MovieName, ScreeningCity, Genre)**
  - **Key: {MovieName, ScreeningCity, Genre)**
  - **All columns are a part of the only candidate key, hence BCNF**
  - **Many Movies can have the same Genre**
  - **Many Cities can have the same movie**
  - **Violates 4NF**

| Movie | ScreeningCity | Genre |
|---|---|---|
| Sholay | Lucknow | Action |
| Sholay | Delhi | Action |
| Lagaan | Mumbai | Drama |
| 3 Idiots | Pune | Drama |
| 1920 | Delhi | Horror |

# Fourth Normal Form (4NF)

- **Example 2 (Not in 4NF)**
- Scheme → {Employee, Skill, Language}
  - Key → {Employee, Skill, Language }
  - Each employee can speak multiple languages
  - Each employee can have multiple skills
  - Thus violates 4NF

| Employee | Skill | Language |
|---|---|---|
| 1234 | Singing | C++ |
| 1234 | Singing | Java |
| 1453 | Cooking | Python |
| 1453 | Singing | Python |
| 2345 | Singing | Python |

# 4NF - Decomposition

- Move the two multi-valued relations to separate tables
- Identify a primary key for each of the new entity.

- **Example 1 (Convert to 3NF)**

  Old Scheme → {MovieName, ScreeningCity, Genre}

  New Scheme → {MovieName, ScreeningCity}

  New Scheme → {MovieName, Genre}

| Movie | Genre |
|---|---|
| Sholay | Action |
| Lagaan | Drama |
| 1920 | Horror |
| 3 Idiots | Drama |

| Movie | ScreeningCity |
|---|---|
| Sholay | Lucknow |
| Sholay | Delhi |
| Lagaan | Mumbai |
| 3 Idiots | Pune |
| 1920 | Delhi |

# 4NF - Decomposition

**Example 2 (Convert to 4NF)**

Old Scheme → {Employee, Skill, Language}

New Scheme → {Employee, Skill}

New Scheme → {Employee, Language}

| Employee | Skill |
|---|---|
| 1234 | Singing |
| 1453 | Cooking |
| 1453 | Singing |
| 2345 | Singing |

| Employee | Language |
|---|---|
| 1234 | C++ |
| 1234 | Java |
| 1453 | Python |
| 2345 | Python |

# Fifth Normal Form (5NF)

- Fifth normal form is satisfied when all tables are broken into as many tables as possible in order to avoid redundancy. Once it is in fifth normal form it cannot be broken into smaller relations without changing the facts or the meaning.

# Domain Key Normal Form (DKNF)

- The relation is in DKNF when there can be no insertion or deletion anomalies in the database.
- Domain-key normal form (DKNF) is a normal form used in database which requires that the database contains no constraints other than **domain constraints** and **key constraints**.

# De-Normalization