



Data Modeling × One Big Table

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
<i>2001: A Space Odyssey</i>	<i>English</i>	<i>1968</i>	<i>142</i>	<i>Sci-fi, Adventure</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Shining</i>	<i>English</i>	<i>1980</i>	<i>144 (US), 119 (EU)</i>	<i>Drama, Horror,</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>A Clockwork Orange</i>	<i>English</i>	<i>1971</i>	<i>136</i>	<i>Crime, Drama, Sci-Fi</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Birds</i>	<i>English</i>	<i>1963</i>	<i>119</i>	<i>Drama, Horror</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
<i>Psycho</i>	<i>English</i>	<i>1960</i>	<i>109</i>	<i>Horror, Mystery, Thriller</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>

Forget about data modeling in RDBMS
i.e., conceptual (ER), logical (relational) & physical (SQL) levels

Data Modeling × One Big Table

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
2001: A Space Odyssey	English	1968	142	Sci-fi, Adventure	Stanley	Kubrick	Jul. 26, 1928	USA
The Shining	English	1980	144 (US), 119 (EU)	Drama, Horror,	Stanley	Kubrick	Jul. 26, 1928	USA
A Clockwork Orange	English	1971	136	Crime, Drama, Sci-Fi	Stanley	Kubrick	Jul. 26, 1928	USA
The Birds	English	1963	119	Drama, Horror	Alfred	Hitchcock	Aug. 13, 1899	England
Psycho	English	1960	109	Horror, Mystery, Thriller	Alfred	Hitchcock	Aug. 13, 1899	England

Redundancy: repeated directors, genres!

+ Simple

- Not efficient! Why?

Data Modeling × One Big Table

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
2001: A Space Odyssey	English	1968	142	Sci-fi, Adventure	Stanley	Kubrick	Jul. 26, 1928	USA
The Shining	English	1980	144 (US), 119 (EU)	Drama, Horror,	Stanley	Kubrick	Jul. 26, 1928	America
A Clockwork Orange	English	1971	136	Crime, Drama, Sci-Fi	Stanley	Kubrick	Jul. 26, 1928	USA
The Birds	English	1963	119	Drama, Horror	Alfred	Hitchcock	Aug. 13, 1899	England
Psycho	English	1960	109	Horror, Mystery, Thriller	Alfred	Hitchcock	Aug. 13, 1899	England

UPDATE

An edit to a director info needs an update on all his movies.
Otherwise, there would be inconsistencies!

An update to a genre's title, ...

Data Modeling × One Big Table

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
<i>2001: A Space Odyssey</i>	<i>English</i>	<i>1968</i>	<i>142</i>	<i>Sci-fi, Adventure</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Shining</i>	<i>English</i>	<i>1980</i>	<i>144 (US), 119 (EU)</i>	<i>Drama, Horror,</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>America</i>
<i>A Clockwork Orange</i>	<i>English</i>	<i>1971</i>	<i>136</i>	<i>Crime, Drama, Sci-Fi</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Birds</i>	<i>English</i>	<i>1963</i>	<i>119</i>	<i>Drama, Horror</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
<i>Psycho</i>	<i>English</i>	<i>1960</i>	<i>109</i>	<i>Horror, Mystery, Thriller</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
					<i>Roman</i>	<i>Polanski</i>	<i>Aug. 18, 1933</i>	<i>France</i>

INSERT

Adding a new director should be with a movie.
Otherwise, there would be empty spaces!

Adding a new genre, ...

Data Modeling × One Big Table

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
2001: A Space Odyssey	English	1968	142	Sci-fi, Adventure	Stanley	Kubrick	Jul. 26, 1928	USA
The Shining	English	1980	144 (US), 119 (EU)	Drama, Horror,				
A Clockwork Orange	English	1971	136	Crime, Drama, Sci-Fi	Stanley	Kubrick	Jul. 26, 1928	USA
The Birds	English	1963	119	Drama, Horror, on	Alfred	Hitchcock	Aug. 13, 1899	England
Psycho	English	1960	109	Horror, Mystery, Thriller	Alfred	Hitchcock	Aug. 13, 1899	England

DELETE

Removing a director must be done for all his movies.
Otherwise, there would be inconsistencies!

Removing a genre, ...

Data Modeling × Anomaly

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Anomaly | Inconsistency

Something that deviates from our expectations

To avoid anomaly in RDBMS

Data Integrity | Integrity Constraints

SQL × DML × Data Integrity

Data Integrity | Integrity Constraints MUST always be assured by DBMS.

ACID Properties (Atomicity, Consistency, Isolation, Durability)

INSERT, UPDATE, DELETE will fail and their effect will be rolled backed if they violate (conflict with) any integrity constraints!

SQL × DML × Data Integrity

- I) Domain Integrity
- II) Entity Integrity
- III) Referential Integrity
- IV) User-defined Integrity

id=2 →

id=4

(2, ~~5~~)

(2, 10)

Data Modeling × Normalization

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To avoid anomaly in RDBMS

→ Table decomposition (normalization) to minimize redundancy and improve data integrity.

Data Modeling × Normalization

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
<i>2001: A Space Odyssey</i>	<i>English</i>	<i>1968</i>	<i>142</i>	<i>Sci-fi, Adventure</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Shining</i>	<i>English</i>	<i>1980</i>	<i>144 (US), 119 (EU)</i>	<i>Drama, Horror,</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>A Clockwork Orange</i>	<i>English</i>	<i>1971</i>	<i>136</i>	<i>Crime, Drama, Sci-Fi</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Birds</i>	<i>English</i>	<i>1963</i>	<i>119</i>	<i>Drama, Horror</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
<i>Psycho</i>	<i>English</i>	<i>1960</i>	<i>109</i>	<i>Horror, Mystery, Thriller</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>



Data Modeling × Normalization

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Movie			
Id	Title	Language	ReleaseDate
1	2001: A Space Odyssey	1	1968
2	The Shining	1	1980
3	A Clockwork Orange	1	1971
4	The Birds	1	1963
5	Psycho	1	1960

Director				
Id	FirstName	LastName	DateOfBirth	PlaceOfBirth
1	Stanley	Kubrick	Jul. 26, 1928	USA
2	Alfred	Hitchcock	Aug. 13, 1899	England

Language	
Id	Title
1	English

Genre	
Id	Title
1	Sci-fi
2	Drama
3	Crime
4	Mystery
5	Thriller
6	Adventure
7	Horror

MovieGenre	
Movielid	Genrelid
1	1
1	6
2	2
2	7
3	3
3	2
3	1
4	2
4	7
5	7
5	4
5	5

MovieDirector	
Movielid	DirectorId
1	1
2	1
3	1
4	2
5	2

MovieRunningTime		
Movielid	RunningTime	Scope
1	142	Globe
2	144	US
2	119	EU
3	136	Globe
3	119	Globe
3	109	Globe

Data Modeling × Normalization

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Given a big table of all information, the process of decomposing it into tables in order to avoid **redundancy** and improve **data integrity**.

Machine-based!
Algorithm-based!

No conceptual level design. No E/R!

No semantics!

Were all we did so far a waste of time and effort?

Data Modeling × Normalization

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Given a big table of all information, the process of decomposing it into tables in order to avoid redundancy and improve data integrity.

Machine-based!
Algorithm-based!

No conceptual level design. No E/R!

At conceptual or logical levels, we do not have actual data!

Data Modeling × Normalization

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- I) Functional Dependencies
- II) Normal Forms

Data Modeling × Normalization

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I) Functional Dependencies

II) Normal Forms

Functional Dependencies

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A functional dependency occurs when the value of one (set of) attribute(s) determines the value of a second (set of) attribute(s)

Functional Dependencies

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
<u>2001: A Space Odyssey</u>	English	1968	142	Sci-fi, Adventure	Stanley	Kubrick	Jul. 26, 1928	USA
<u>The Shining</u> ←	English	1980	144 (US), 119 (EU)	<u>Drama, Horror</u>	Stanley	Kubrick	Jul. 26, 1928	USA
<u>A Clockwork Orange</u>	English	1971	136	Crime, Drama, Sci-Fi	Stanley	Kubrick	Jul. 26, 1928	USA
<u>The Birds</u> ←	English	1963	119	<u>Drama, Horror</u>	Alfred	Hitchcock	Aug. 13, 1899	England
<u>Psycho</u>	English	1960	109	<u>Horror, Mystery, Thriller</u>	Alfred	Hitchcock	Aug. 13, 1899	England

Title → Title

(Title, ReleaseDate) → FirstName ✓

(Title, ReleaseDate) → (FirstName, LastName)

Title → Genre ✓

Genre ↗ Title ✗

Functional Dependencies

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
<i>2001: A Space Odyssey</i>	<i>English</i>	<i>1968</i>	<i>142</i>	<i>Sci-fi, Adventure</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Shining</i>	<i>English</i>	<i>1980</i>	<i>144 (US), 119 (EU)</i>	<i>Drama, Horror,</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>A Clockwork Orange</i>	<i>English</i>	<i>1971</i>	<i>136</i>	<i>Crime, Drama, Sci-Fi</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Birds</i>	<i>English</i>	<i>1963</i>	<i>119</i>	<i>Drama, Horror</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
<i>Psycho</i>	<i>English</i>	<i>1960</i>	<i>109</i>	<i>Horror, Mystery, Thriller</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>

Title → Title

(Title, ReleaseDate) → FirstName

(Title, ReleaseDate) → (FirstName, LastName)

Title → Genre

Genre ↗ Title



Functional Dependencies

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
2001: A Space Odyssey	English	1968	142	Sci-fi, Adventure	Stanley	Kubrick	Jul. 26, 1928	USA
The Shining	English	1980	144 (US), 119 (EU)	Drama, Horror,	Stanley	Kubrick	Jul. 26, 1928	USA
A Clockwork Orange	English	1971	136	Crime, Drama, Sci-Fi	Stanley	Kubrick	Jul. 26, 1928	USA
The Birds	English	1963	119	Drama, Horror	Alfred	Hitchcock	Aug. 13, 1899	England
Psycho	English	1960	109	Horror, Mystery, Thriller	Alfred	Hitchcock	Aug. 13, 1899	England

Title \rightarrow Title

(Title, ReleaseDate) \rightarrow FirstName

(Title, ReleaseDate) \rightarrow (FirstName, LastName)

Genre \nrightarrow Title

Composite
Determinant

Functional Dependencies

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Functional dependencies may be based on equations, e.g., in derived attributes:

TotalPrice = Quantity × UnitPrice
(Quantity, UnitPrice) → TotalPrice

$$f(a) = b * c$$
$$b, c \rightarrow f(a)$$

But,

$$\text{unit} \rightarrow \text{TotalPrice}$$

$$ph = \text{area}(\text{od} + \text{local} + \text{cod} + \text{t} + \text{x})$$
$$x, \text{od}, \text{lo} \rightarrow ph$$

Not Limited to
Equation or
Function

Functional Dependencies

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
2001: A Space Odyssey	English	1968	142	Sci-fi, Adventure	Stanley	Kubrick	Jul. 26, 1928	USA,
The Shining	English	1980	144 (US), 119 (EU)	Drama, Horror,	Stanley	Kubrick	Jul. 26, 1928	USA
A Clockwork Orange	English	1971	136	Crime, Drama, Sci-Fi	Stanley	Kubrick	Jul. 26, 1928	USA
The Birds	English	1963	119	Drama, Horror	Alfred	Hitchcock	Aug. 13, 1899	England
Psycho	English	1960	109	Horror, Mystery, Thriller	Alfred	Hitchcock	Aug. 13, 1899	England

Functional dependencies are based on the existing data:

Title → ReleaseDate

Title → Genre

Title → FirstName, LastName

PlaceOfBirth → FirstName ✓

Functional Dependencies

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
2001: A Space Odyssey	English	1968	142	Sci-fi, Adventure	Stanley	Kubrick	Jul. 26, 1928	USA
The Shining	English	1980	144 (US), 119 (EU)	Drama, Horror,	Stanley	Kubrick	Jul. 26, 1928	USA
A Clockwork Orange	English	1971	136	Crime, Drama, Sci-Fi	Stanley	Kubrick	Jul. 26, 1928	USA
The Birds	English	1963	119	Drama, Horror	Alfred	Hitchcock	Aug. 13, 1899	England
Psycho	English	1960	109	Horror, Mystery, Thriller	Alfred	Hitchcock	Aug. 13, 1899	England
Psycho	English	1998	104	Horror, Mystery, Thriller	Gus	Van Sant	July 24, 1952	USA

Functional dependencies are based on the existing data:

- Title \nrightarrow ReleaseDate ✗
- Title \rightarrow Genre
- Title \nrightarrow FirstName, LastName

Functional Dependencies

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
2001: A Space Odyssey	English	1968	142	Sci-fi, Adventure	Stanley	Kubrick	Jul. 26, 1928	USA
The Shining	English	1980	144 (US), 119 (EU)	Drama, Horror,	Stanley	Kubrick	Jul. 26, 1928	USA
A Clockwork Orange	English	1971	136	Crime, Drama, Sci-Fi	Stanley	Kubrick	Jul. 26, 1928	USA
The Birds	English	1963	119	Drama, Horror	Alfred	Hitchcock	Aug. 13, 1899	England
<u>Psycho</u>	English	1960	109	<u>Horror, Mystery, Thriller</u>	Alfred	Hitchcock	Aug. 13, 1899	England
<u>Psycho</u>	English	1998	104	Horror, Mystery, Thriller	Gus	Van Sant	July 24, 1952	USA

Determinant might not be unique:

Title → Genre ✓

FirstName → LastName

Functional Dependencies

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
<i>2001: A Space Odyssey</i>	<i>English</i>	<i>1968</i>	<i>142</i>	<i>Sci-fi, Adventure</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Shining</i>	<i>English</i>	<i>1980</i>	<i>144 (US), 119 (EU)</i>	<i>Drama, Horror,</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>A Clockwork Orange</i>	<i>English</i>	<i>1971</i>	<i>136</i>	<i>Crime, Drama, Sci-Fi</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Birds</i>	<i>English</i>	<i>1963</i>	<i>119</i>	<i>Drama, Horror</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
<i>Psycho</i>	<i>English</i>	<i>1960</i>	<i>109</i>	<i>Horror, Mystery, Thriller</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
<i>Psycho</i>	<i>English</i>	<i>1998</i>	<i>104</i>	<i>Horror, Mystery, Thriller</i>	<i>Gus</i>	<i>Van Sant</i>	<i>July 24, 1952</i>	<i>USA</i>

But if a determinant is unique, then ...

Functional Dependencies

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Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
2001: A Space Odyssey	English	1968	142	Sci-fi, Adventure	Stanley	Kubrick	Jul. 26, 1928	USA
The Shining	English	1980	144 (US), 119 (EU)	Drama, Horror,	Stanley	Kubrick	Jul. 26, 1928	USA
A Clockwork Orange	English	1971	136	Crime, Drama, Sci-Fi	Stanley	Kubrick	Jul. 26, 1928	USA
The Birds	English	1963	119	Drama, Horror	Alfred	Hitchcock	Aug. 13, 1899	England
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Psycho	English	1998	104	Horror, Mystery, Thriller	Gus	Van Sant	July 24, 1952	USA

But if a determinant is unique, then it is determinant of ALL other attributes.

RunningTime → Title, Language, ..., PlaceOfBirth
ReleaseDate → Title, Language, ..., PlaceOfBirth

Functional Dependencies

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Table				
A	B	C	D	E
<u>1</u>	<u>1</u>	<u>1</u>	1	1
<u>1</u>	<u>1</u>	<u>2</u>	1	1
2	1	1	1	1
2	2	1	2	1
2	2	2	3	2

BC \rightarrow D ✓

B \rightarrow A ✗

D \rightarrow BE ✓

AB \rightarrow C ✗

Functional Dependencies

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Table				
A	B	C	D	E
1	1	1	1	1
1	1	2	1	1
2	1	1	1	1
2	2	1	2	1
2	2	2	3	2

BC \rightarrow D

B \nrightarrow A Given B=1, two values for A, 1 or 2

D \rightarrow BE

AB \nrightarrow C Given (A=1,B=1), two values for C, 1 or 2

Functional Dependencies × Rules

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IF	THEN	Not a complete list
----	------	---------------------

$$\textcircled{A} \rightarrow \textcircled{BC}$$

$$A \rightarrow B$$

$$A \rightarrow C$$

$$AB \rightarrow C$$

$$AC \rightarrow B$$

$$\textcircled{A} \text{ ~~FFI~~ } \rightarrow \textcircled{BC}$$

$$\rightarrow \textcircled{B}$$

$$\rightarrow \textcircled{C}$$

$$A \rightarrow B$$

$$B \rightarrow C$$

$$A \rightarrow C$$

Transitivity

$$\textcircled{AB} \rightarrow \textcircled{C}$$

$$\text{HIG} \textcircled{B} \textcircled{A} \rightarrow \textcircled{C}$$

$$A \rightarrow C$$

$$B \rightarrow C$$

$$A \rightarrow BC$$

Be Careful!

$$\textcircled{A} \rightarrow \textcircled{B}$$

$$\textcircled{A} \rightarrow \textcircled{C}$$

$$\rightarrow B \rightarrow C$$

$$C \rightarrow B$$

Be Careful!

Functional Dependencies × Trivial

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A functional dependency is trivial if it is **satisfied by every tables**

$A \rightarrow A$
 $AB \rightarrow A$
 $AB \rightarrow B$

Generally, $X \rightarrow Y$, where $Y \subseteq X$.

Trivial FD does not make a significant statement about real world constraints and we only interested in non-trivial FD's.

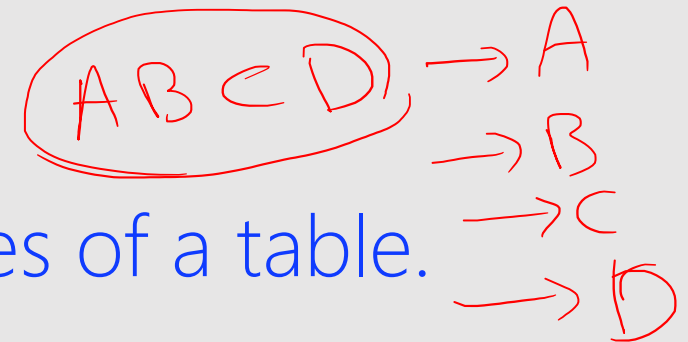
$\left\{ \begin{array}{l} \rightarrow AC \\ ABCD \rightarrow A \\ \rightarrow BC \\ \rightarrow CD \\ \rightarrow BCD \end{array} \right.$

Functional Dependencies × Super Key 28

Super Key is a set of attributes that functionally determines ALL the attributes in a table.

Super Key is a set of attributes that identify an entity (row) uniquely.

The trivial Super Key is a set of all attributes of a table.



Functional Dependencies × Super Key 29

Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
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The Shining	English	1980	144 (US), 119 (EU)	Drama, Horror,	Stanley	Kubrick	Jul. 26, 1928	USA
A Clockwork Orange	English	1971	136	Crime, Drama, Sci-Fi	Stanley	Kubrick	Jul. 26, 1928	USA
The Birds	English	1963	119	Drama, Horror	Alfred	Hitchcock	Aug. 13, 1899	England
Psycho	English	1960	109	Horror, Mystery, Thriller	Alfred	Hitchcock	Aug. 13, 1899	England
Psycho	English	1998	104	Horror, Mystery, Thriller	Gus	Van Sant	July 24, 1952	USA

Super Key:

A) {Title, Language, ..., DateOfBirth, PlaceOfBirth}

~~B) {Title} → lang (RD)~~

? C) {Title, Language, Genre} X

? D) {Title, ReleaseDate} ✓

Functional Dependencies × Super Key 30

Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
<i>2001: A Space Odyssey</i>	<i>English</i>	<i>1968</i>	<i>142</i>	<i>Sci-fi, Adventure</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Shining</i>	<i>English</i>	<i>1980</i>	<i>144 (US), 119 (EU)</i>	<i>Drama, Horror,</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>A Clockwork Orange</i>	<i>English</i>	<i>1971</i>	<i>136</i>	<i>Crime, Drama, Sci-Fi</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Birds</i>	<i>English</i>	<i>1963</i>	<i>119</i>	<i>Drama, Horror</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
<i>Psycho</i>	<i>English</i>	<i>1960</i>	<i>109</i>	<i>Horror, Mystery, Thriller</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
<i>Psycho</i>	<i>English</i>	<i>1998</i>	<i>104</i>	<i>Horror, Mystery, Thriller</i>	<i>Gus</i>	<i>Van Sant</i>	<i>July 24, 1952</i>	<i>USA</i>

Super Key:

- A) {Title, Language, ..., DateOfBirth, PlaceOfBirth} ✓
- B) {Title} ✗ cannot determine the ReleaseDate
- C) {Title, Language, Genre} ✗ cannot determine the ReleaseDate
- D) {Title, ReleaseDate} ✓

Functional Dependencies × Candidate Key 31

Candidate Key is a minimal Super Key.

Super Key is minimal if it is not possible to remove an attribute from it. Otherwise, it is not Super Key anymore.

Candidate Key is NOT a super key with smallest size!

Functional Dependencies × Candidate Key 32

Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
<i>2001: A Space Odyssey</i>	<i>English</i>	<i>1968</i>	<i>142</i>	<i>Sci-fi, Adventure</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Shining</i>	<i>English</i>	<i>1980</i>	<i>144 (US), 119 (EU)</i>	<i>Drama, Horror,</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>A Clockwork Orange</i>	<i>English</i>	<i>1971</i>	<i>136</i>	<i>Crime, Drama, Sci-Fi</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Birds</i>	<i>English</i>	<i>1963</i>	<i>119</i>	<i>Drama, Horror</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
<i>Psycho</i>	<i>English</i>	<i>1960</i>	<i>109</i>	<i>Horror, Mystery, Thriller</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
<i>Psycho</i>	<i>English</i>	<i>1998</i>	<i>104</i>	<i>Horror, Mystery, Thriller</i>	<i>Gus</i>	<i>Van Sant</i>	<i>July 24, 1952</i>	<i>USA</i>

Candidate Key (Minimal Super Key):

A) {Title, Language, ..., DateOfBirth, PlaceOfBirth} ○

B) {~~Title~~, ~~FirstName~~} ○

C) {RunningTime}

D) {ReleaseDate}

Functional Dependencies × Candidate Key 33

Movie								
Title	Language	ReleaseDate	RunningTime	Genre	FirstName	LastName	DateOfBirth	PlaceOfBirth
<i>2001: A Space Odyssey</i>	<i>English</i>	<i>1968</i>	<i>142</i>	<i>Sci-fi, Adventure</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Shining</i>	<i>English</i>	<i>1980</i>	<i>144 (US), 119 (EU)</i>	<i>Drama, Horror,</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>A Clockwork Orange</i>	<i>English</i>	<i>1971</i>	<i>136</i>	<i>Crime, Drama, Sci-Fi</i>	<i>Stanley</i>	<i>Kubrick</i>	<i>Jul. 26, 1928</i>	<i>USA</i>
<i>The Birds</i>	<i>English</i>	<i>1963</i>	<i>119</i>	<i>Drama, Horror</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
<i>Psycho</i>	<i>English</i>	<i>1960</i>	<i>109</i>	<i>Horror, Mystery, Thriller</i>	<i>Alfred</i>	<i>Hitchcock</i>	<i>Aug. 13, 1899</i>	<i>England</i>
<i>Psycho</i>	<i>English</i>	<i>1998</i>	<i>104</i>	<i>Horror, Mystery, Thriller</i>	<i>Gus</i>	<i>Van Sant</i>	<i>July 24, 1952</i>	<i>USA</i>

Candidate Key (Minimal Super Key):

A) {Title, Language, ..., DateOfBirth, PlaceOfBirth} ✗

B) {Title, FirstName} ✓

C) {RunningTime} ✓

D) {ReleaseDate} ✓

Functional Dependencies × Primary Key

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Primary Key is a Candidate Key selected out of multiple Candidate Keys.

- A) (Title, FirstName)
- B) (RunningTime)
- C) (ReleaseDate)

Best Practice: The best candidate for Primary Key:

- I) Less #attributes AND
- II) The attributes are mandatory (must have value)

Functional Dependencies × Keys

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Consider the table $T(A, B, C, D)$ and the following functional dependencies: $B \rightarrow D$, $ACD \rightarrow B$, $BC \rightarrow A$

$\rightarrow A$
 $\rightarrow C$
 $\rightarrow D$

$\rightarrow B$
 $\rightarrow C$
 $\rightarrow D$

Super Keys?

Candidate Keys?

Primary Key?

Functional Dependencies × Keys

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Consider the table $T(A, B, C, D)$ and the following functional dependencies: $B \rightarrow D$, $ACD \rightarrow B$, $BC \rightarrow A$

Super Keys?

$SK1 = \{A, B, C, D\}$, $SK2 = \{A, C, D\}$, $SK3 = \{B, C\}$

Candidate Keys?

$CK1 = \{A, C, D\}$, $CK2 = \{B, C\}$

Primary Key?

$PK = \{A, C, D\} \mid PK = \{B, C\}$

$BC \rightarrow A$

$B \rightarrow D$

$BC \rightarrow D$

Data Modeling × Normalization

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- I) Functional Dependencies
- II) Normal Forms