

The Relational Model

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Recap

- The relational model is based on the concept of a relation or table.
- Two example relations:

Teams	Name	Home Field	Coach
	Rangers	Runnymede CI	Tarvo Sinervo
	Ducks	Humber Public	Tracy Zheng
	Choppers	High Park	Ammar Jalali

Games	Home team	Away team	Home goals	Away goals
	Rangers	Ducks	3	0
	Ducks	Choppers	1	1
	Rangers	Choppers	4	2
	Choppers	Ducks	0	5

Relations in Math

- A domain is a set of values.
- Suppose D_1, D_2, \dots, D_n are domains.
 - The **Cartesian product** $D_1 \times D_2 \times \dots \times D_n$ is the set of all tuples $\langle d_1, d_2, \dots, d_n \rangle$ such that $d_1 \in D_1, d_2 \in D_2, \dots, d_n \in D_n$.
 - I.e., every combination of a value from D_1 , a value from D_2 etc.
- A **(mathematical) relation** on D_1, D_2, \dots, D_n is a subset of the Cartesian product.

Example

- Example of a mathematical relation:
 - Let $A = \{p, q, r, s\}$, $B = \{1, 2, 3\}$ and $C = \{100, 200\}$.
 - $R = \{ \langle q, 2, 100 \rangle, \langle s, 3, 200 \rangle, \langle p, 1, 200 \rangle \}$ is a relation on A, B, C .
- Our database tables are relations too.
- Example:
 $\{ \langle \text{Rangers}, \text{Ducks}, 3, 0 \rangle, \langle \text{Ducks}, \text{Choppers}, 1, 1 \rangle, \langle \text{Rangers}, \text{Choppers}, 4, 2 \rangle, \langle \text{Choppers}, \text{Ducks}, 0, 5 \rangle \}$

Relation schemas vs instances

- **Schema**: definition of the structure of the relation.
 - **Example:**

Teams have 3 attributes: name, home field, coach.
No two teams can have the same name.
 - **Notation** for expressing a relation's schema
Teams(Name, HomeField, Coach)
- **Instance**: particular data in the relation.
 - Instances change constantly; schemas rarely.
- Conventional databases store the current version of the data. Databases that record the history are called *temporal* databases.

Terminology

Teams	Name	Home Field	Coach
	Rangers	Runnymede CI	Tarvo Sinervo
	Ducks	Humber Public	Tracy Zheng
	Choppers	High Park	Ammar Jalali
	Crullers	WTCS	Anna Liu

- **Relation** (table)
- **Attribute** (column)
- **Tuple** (row)
- **Arity (or Degree)** of a relation: number of attributes
- **Cardinality** of a relation: number of tuples

Relations are **sets**

- A relation is a **set** of tuples, which means:
 - there can be no duplicate tuples
 - order of the tuples doesn't matter
- In another model, relations are **bags**
 - aka **multi-sets**
 - allows duplicates
- Most commercial DBMSs use bag model.
- But for now, we will stick with relations as sets.

Database schemas and instances

- **Database schema:** a set of relation schemas
- **Database instance:** a set of relation instances

A schema for our league data

Teams(name, homefield, coach)

Games(hometeam, awayteam, homegoals, awaygoals)

- Can there be >1 team with the same name?
 - Didn't happen in our dataset, but could it?
 - That's up to the league, not us!
- Suppose the league wants to allow
 - multiple teams with same name
 - multiple teams with same home field
- The schema allows it: nothing says otherwise.
- But what if the league wants to disallow multiple teams with the same name *and* home field?

Constraining the data

- More formally: \nexists tuples t_1 and t_2 such that
 $(t_1.name = t_2.name) \wedge$
 $(t_1.homefield = t_2.homefield)$
- Implication: If we know the values for {name, homefield}, we can look up ***exactly*** one team in the relation.
- I.e., attributes {name, homefield} uniquely identify tuples in this relation.
- We say that {name, homefield} is a “***superkey***” for relation Teams.

Superkeys

- Informally:
A **superkey** is a set of one or more attributes whose combined values are unique.
 - i.e., no two tuples can have the same values on all of these attributes.
- Formally: if attributes a_1, a_2, \dots, a_n form a **superkey** for relation R , \nexists tuples t_1 and t_2 such that
$$(t_1.a_1 = t_2.a_1) \wedge (t_1.a_2 = t_2.a_2) \wedge \dots \wedge (t_1.a_n = t_2.a_n)$$

Example

- Course(dept, number, name, breadth)
 - One tuple might be
<“csc”, “343”, “Introduction to Databases”, True>
- Suppose our knowledge of the domain tells us that no two tuples can have the same value for dept and number.
- This means that {dept, number} is a superkey.
- This is a constraint on what can go in the relation.
- Create an instance of Course that violates it.
- Does every relation have a superkey?

Keeping it minimal

- If $\{\text{dept}, \text{number}\}$ is a superkey, then so is $\{\text{dept}, \text{number}, \text{name}\}$.
 - This follows from the definition.
- But we are more interested in a ***minimal*** set of attributes with the superkey property.
 - Minimal in the sense that no attributes can be removed from the superkey without making it no longer a superkey.

Keys

- **key**: a minimal superkey.
- In the schema, by convention we often
 - underline a key.
- Aside: The term “superkey” is related to the term “superset”.
 - A superkey is a superset of some key.
(Not necessarily a proper superset.)
- Can a relation have more than one key?

Coincidence vs key

- If a set of attributes is a key for a relation:
 - It does not mean ***merely*** that there are no duplicates in a particular instance of the relation
 - It means that in principle there *cannot* be any even if the content of the relation changes.
 - Only a domain expert can determine what is a key.
- Often we invent an attribute to ensure all tuples will be unique.
This predates databases.
E.g., SIN, ISBN number.
- A key defines a kind of **integrity constraint**.

“Primary key”??

- This is specific to SQL and we’ll learn about it later.
 - one of keys, chosen as the one to use for indexing and other functions in the SQL DBMS

Example: Movies schema

References between relations

- Relations often refer to each other.
- Example:
In the Roles relation, the tuple about Han Solo needs to say he is played by Ford.
- Rather than repeat information already in the Artists table, we store Ford's key.
- If aID is a key for Artists, does that mean a particular aID can appear only once in Roles??

Foreign keys

- The referring attribute is called a **foreign key** because it refers to an attribute that is a key in another table.
- This gives us a way to refer to a single tuple in that relation.
- A foreign key may need to have several attributes.

Example

□ In relation Players, team is a foreign key on tID in relation Teams.

Teams	tID	country	olympics	coach
	71428	Canada	2010	Davidson
	10001	Canada	1994	Babcock
	22324	USA	2010	Wilson

Players	pID	name	team	position
	8812	Szabados	71428	goal
	1324	MacLeod	71428	right defense
	9876	Agosta	71428	left wing
	1553	Hunter	10001	centre

Declaring foreign keys

- A bit of notation: $R[A]$
 - R is a relation and A is a list of attributes in R .
 - $R[A]$ is the set of all tuples from R , but with only the attributes in list A .
- We declare foreign key constraints this way:
 $R_1[X] \subseteq R_2[Y]$
 - X and Y may be lists of attributes, of same arity
 - Y must be a key in R_2
- Example: $\text{Roles}[\text{mID}] \subseteq \text{Movies}[\text{mID}]$

Example: Movies schema handout

Referential integrity constraints

- These $R_1[X] \subseteq R_2[Y]$ relationships are a kind of **referential integrity constraint** or **inclusion dependency**.
- Not all referential integrity constraints are foreign key constraints.
- For example, we could say
 $\text{Artists}[\text{aID}] \subseteq \text{Roles}[\text{aID}]$
Here we are not referring to a unique tuple.
- $R_1[X] \subseteq R_2[Y]$ is a foreign key constraint iff Y is a key for relation R_2 .

Designing a schema

- Mapping from the real world to a relational schema is surprisingly challenging and interesting.
- There are always many possible schemas.
- Two important goals:
 - Represent the data well.
For example, avoid constraints that prevent expressing things that occur in the domain.
 - Avoid redundancy.
- Later, we'll learn some elegant theory that provides sound principles for good design.

Designing a schema: example

Da Mario		
Receipt No: 1357		
Date: 5/5/92		
3	covers	3.00
2	hors d'oeuvre	5.00
3	first course	9.00
2	steak	12.00
Total:		29.00

Da Mario		
Receipt No: 2334		
Date: 4/7/92		
2	covers	2.00
2	hors d'oeuvre	2.50
2	first course	6.00
2	bream	15.00
2	coffee	2.00
Total:		27.50

Da Mario		
Receipt No: 3007		
Date: 4/8/92		
2	covers	3.00
2	hors d'oeuvre	6.00
3	first course	8.00
1	bream	7.50
1	salad	3.00
2	coffee	2.00
Total:		29.50

What's next

- We will learn how to use SQL to
 - define a database's structure,
 - put data in it, and
 - write queries on it.
- First we'll learn how to write queries in relational algebra.
 - Relational algebra is the foundation of SQL.
 - Other important concepts, like query optimization, are defined in terms of RA.