CMSC424: Database Design
SQL

February 17, 2020

Instructor: Amol Deshpande
amol@cs.umd.edu

Today's Plan

- SQL (Chapter 3, 4) – Remaining Stuff
  - Triggers (5.3)
  - Authorization (4.6), Ranking (5.5)
  - Some Complex SQL Examples
- Project 1 discussion on Wednesday
- Entity-Relationship Modeling
- Wednesday: Anatomy of a Web Application
  - Project 2

Triggers

- A ***trigger*** is a statement that is executed automatically by the system as a side effect of a modification to the database.

- Suppose that instead of allowing negative account balances, the bank deals with overdrafts by
  - 1. setting the account balance to zero
  - 2. creating a loan in the amount of the overdraft
  - 3. giving this loan a loan number identical to the account number of the overdrawn account

Trigger Example in SQL:1999

create trigger *overdraft-trigger* **after update on** *account*

referencing new row as *nrow*

for each row

when *nrow.balance* < 0

begin atomic

actions to be taken

end

Trigger Example in SQL:1999

```
create trigger overdraft-trigger after update on account
  referencing new row as nrow
  for each row
  when nrow.balance < 0
  begin atomic
        insert into borrower
          (select customer-name, account-number
           from depositor
           where nrow.account-number = depositor.account-number);
       insert into loan values
          (nrow.account-number, nrow.branch-name, nrow.balance);
       update account set balance = 0
        where account.account-number = nrow.account-number
  end
```

Triggers…

- External World Actions
  - How does the DB *order* something if the inventory is low ?
- Syntax
  - Every system has its own syntax
- Careful with triggers
  - Cascading triggers, Infinite Sequences…
- More Info/Examples:
  - http://www.adp-gmbh.ch/ora/sql/create_trigger.html
  - Google: “create trigger” oracle download-uk

Recursion in SQL

- Example: find which courses are a prerequisite, whether directly or indirectly, for a specific course

```
with recursive rec_prereq(course_id, prereq_id) as (
        select course_id, prereq_id
        from prereq
    union
        select rec_prereq.course_id, prereq.prereq_id,
        from rec_rereq, prereq
        where rec_prereq.prereq_id = prereq.course_id
    )
select *
from rec_prereq;
```

Makes SQL Turing Complete (i.e., you can write any program in SQL)

But: Just because you can, doesn't mean you should

Ranking

- Ranking is done in conjunction with an order by specification.

- Consider: *student_grades(ID, GPA)*

- Find the rank of each student.

```
select ID, rank() over (order by GPA desc) as s_rank
from student_grades
order by s_rank
```

- Equivalent to:

```
select ID, (1 + (select count(*)
                 from student_grades B
                 where B.GPA > A.GPA)) as s_rank
from student_grades A
order by s_rank;
```

Authorization/Security

- GRANT and REVOKE keywords
  - **grant select on** *instructor* **to** U_1, U_2, U_3
  - **revoke select on** *branch* **from** U_1, U_2, U_3
- Can provide select, insert, update, delete priviledges
- Can also create "Roles" and do security at the level of roles
- Some databases support doing this at the level of individual "tuples"
  - MS SQL Server: https://docs.microsoft.com/en-us/sql/relational-databases/security/row-level-security?view=sql-server-ver15
  - PostgreSQL: https://www.postgresql.org/docs/10/ddl-rowsecurity.html

Fun with SQL

- https://blog.jooq.org/2016/04/25/10-sql-tricks-that-you-didnt-think-were-possible/
  - Long slide-deck linked off of this page
  - Complex SQL queries showing how to do things like: do Mandelbrot, solve subset sum problem etc.

- **The MADlib Analytics Library or MAD Skills, the SQL;** https://arxiv.org/abs/1208.4165

- https://www.red-gate.com/simple-talk/blogs/statistics-sql-simple-linear-regressions/

1. Everything is a Table

```
SELECT *
FROM (
  SELECT *
  FROM person
) t
```

```
SELECT *
FROM (
  VALUES(1),(2),(3)
) t(a)
```

Everything is a table. In PostgreSQL, even functions are tables:

```
SELECT *
FROM substring('abcde', 2, 3)
```

https://blog.jooq.org/2016/04/25/10-sql-tricks-that-you-didnt-think-were-possible/

2. Recursion can be very powerful

```sql
WITH RECURSIVE t(v) AS (
  SELECT 1     -- Seed Row
  UNION ALL
  SELECT v + 1 -- Recursion
  FROM t
)
SELECT v
FROM t
LIMIT 5
```

Makes SQL Turing-Complete

It yields

```
 v
---
 1
 2
 3
 4
 5
```

https://blog.jooq.org/2016/04/25/10-sql-tricks-that-you-didnt-think-were-possible/

3. Window Functions

```
SELECT depname, empno, salary, avg(salary) OVER (PARTITION BY depname) FROM empsalary;
```

```
depname   | empno | salary |          avg
-----------+-------+--------+-----------------------
 develop   |    11 |   5200 | 5020.0000000000000000
 develop   |     7 |   4200 | 5020.0000000000000000
 develop   |     9 |   4500 | 5020.0000000000000000
 develop   |     8 |   6000 | 5020.0000000000000000
 develop   |    10 |   5200 | 5020.0000000000000000
 personnel |     5 |   3500 | 3700.0000000000000000
 personnel |     2 |   3900 | 3700.0000000000000000
 sales     |     3 |   4800 | 4866.6666666666666667
 sales     |     1 |   5000 | 4866.6666666666666667
 sales     |     4 |   4800 | 4866.6666666666666667
(10 rows)
```

https://www.postgresql.org/docs/9.3/tutorial-window.html https://www.red-gate.com/simple-talk/blogs/statistics-sql-simple-linear-regressions/

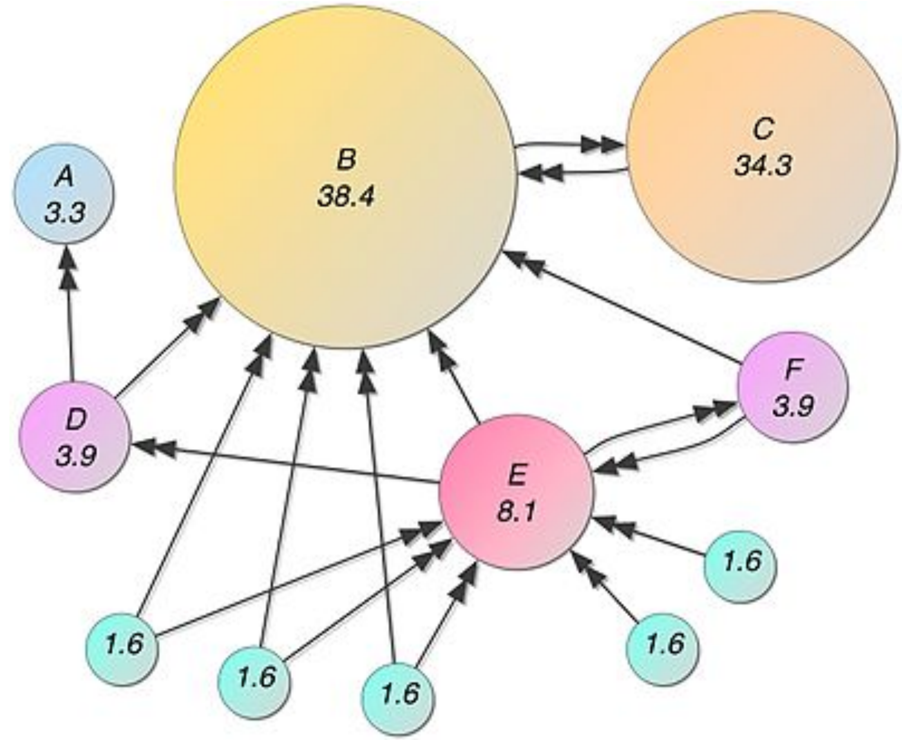
4. Correlation Coefficient

```
SET ARITHABORT ON;

DECLARE @OurData TABLE
    (
    x NUMERIC(18,6) NOT NULL,
    y NUMERIC(18,6) NOT NULL
    );
  INSERT INTO @OurData
    (x, y)
  SELECT
   x,y
   FROM (VALUES
  (1,32),(1,23),(3,50),(11,37),(-2,39),(10,44),(27,32),(25,16),(20,23),
  (4,5),(30,41),(28,2),(31,52),(29,12),(50,40),(43,18),(10,65),(44,26),
  (35,15),(24,37),(52,66),(59,46),(64,95),(79,36),(24,66),(69,58),(88,56),
  (61,21),(100,60),(62,54),(10,14),(22,40),(52,97),(81,26),(37,58),(93,71)
  (64,82),(24,33),(112,49),(64,90),(53,90),(132,61),(104,35),(60,52),
  (29,50),(85,116),(95,104),(131,37),(139,38),(8,124)
  )f(x,y)
  SELECT
    ((Sy * Sxx) - (Sx * Sxy))
    / ((N * (Sxx)) - (Sx * Sx)) AS a,
    ((N * Sxy) - (Sx * Sy))
    / ((N * Sxx) - (Sx * Sx)) AS b,
    ((N * Sxy) - (Sx * Sy))
    / SQRT(
        (((N * Sxx) - (Sx * Sx))
         * ((N * Syy - (Sy * Sy))))) AS r
    FROM
      (
      SELECT SUM([@OurData].x) AS Sx, SUM([@OurData].y) AS Sy,
        SUM([@OurData].x * [@OurData].x) AS Sxx,
        SUM([@OurData].x * [@OurData].y) AS Sxy,
        SUM([@OurData].y * [@OurData].y) AS Syy,
        COUNT(*) AS N
        FROM @OurData
      ) sums;
```

5. Page Rank

- Recursive algorithm to assign weights to the nodes of a graph (Web Link Graph)
- Weight for a node depends on the weights of the nodes that point to it
- Typically done in iterations till "convergence"
- Not obvious that you can do it in SQL, but:
  - Each iteration is just a LEFT OUTERJOIN
  - Stopping condition is trickier
- Other ways to do it as well



https://devnambi.com/2013/pagerank.html

```
declare @DampingFactor decimal(3,2) = 0.85 --set the damping factor
	,@MarginOfError decimal(10,5) = 0.001 --set the stable weight
	,@TotalNodeCount int
	,@IterationCount int = 1

-- we need to know the total number of nodes in the system
set @TotalNodeCount = (select count(*) from Nodes)

-- iterate!
WHILE EXISTS
(
	-- stop as soon as all nodes have converged
	SELECT *
	FROM dbo.Nodes
	WHERE HasConverged = 0
)
BEGIN

	UPDATE n SET
	NodeWeight = 1.0 - @DampingFactor + isnull(x.TransferWeight, 0.0)

	-- a node has converged when its existing weight is the same as the weight it would be given
	-- (plus or minus the stable weight margin of error)
	,HasConverged = case when abs(n.NodeWeight - (1.0 - @DampingFactor + isnull(x.TransferWeight, 0.0))) < @MarginOfError then 1
else 0 end
	FROM Nodes n
	LEFT OUTER JOIN
	(
		-- Here's the weight calculation in place
		SELECT
			e.TargetNodeId
			,TransferWeight = sum(n.NodeWeight / n.NodeCount) * @DampingFactor
		FROM Nodes n
		INNER JOIN Edges e
		  ON n.NodeId = e.SourceNodeId
		GROUP BY e.TargetNodeId
	) as x
	ON x.TargetNodeId = n.NodeId

	-- for demonstration purposes, return the value of the nodes after each iteration
	SELECT
		@IterationCount as IterationCount
		,*
	FROM Nodes

	set @IterationCount += 1
END
```

Today's Plan

- SQL (Chapter 3, 4) – Remaining Stuff
- Entity-Relationship Modeling
  - Entity-relationship Model (E/R model)
  - Converting from E/R to Relational
- Wednesday: Anatomy of a Web Application
  - Project 2

Entity-Relationship Model

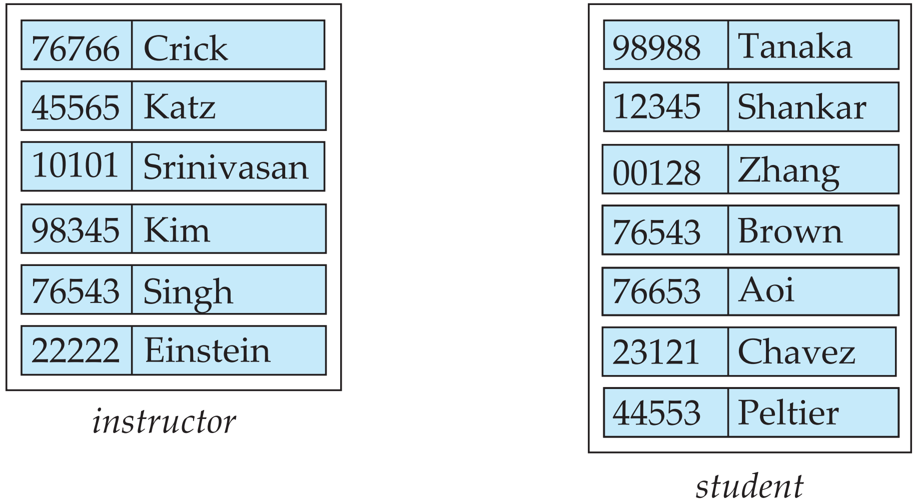
- Two key concepts
  - *Entities*:
    - An object that *exists* and is *distinguishable* from other objects
      - Examples: Bob Smith, BofA, CMSC424
    - Have *attributes* (people have names and addresses)
    - Form *entity sets* with other entities of the same type that share the same properties
      - Set of all people, set of all classes
    - Entity sets may overlap
      - Customers and Employees

Entity-Relationship Model

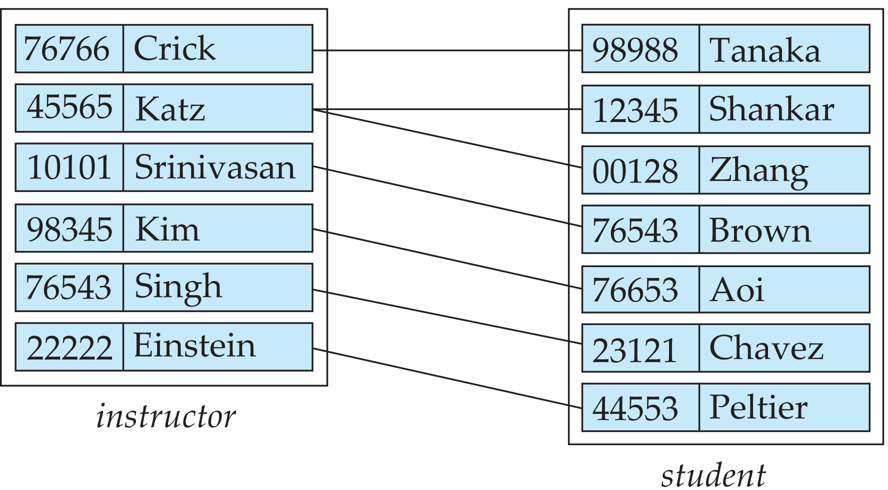
- Two key concepts
  - *Relationships*:
    - Relate 2 or more entities
      - E.g. Bob Smith *has account at* College Park Branch
    - Form *relationship sets* with other relationships of the same type that share the same properties
      - Customers *have accounts at* Branches
    - Can have attributes:
      - *has account at* may have an attribute *start-date*
    - Can involve more than 2 entities
      - Employee *works at* Branch *at* Job

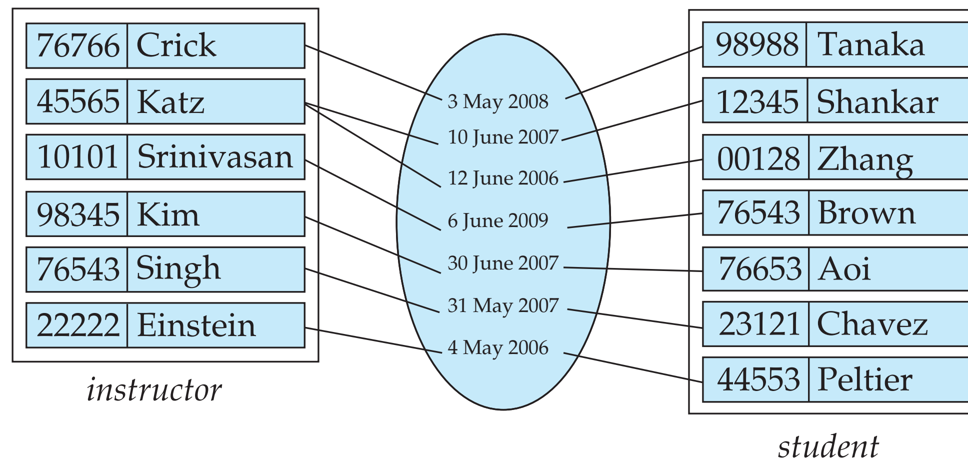
Entities and relationships

Two Entity Sets

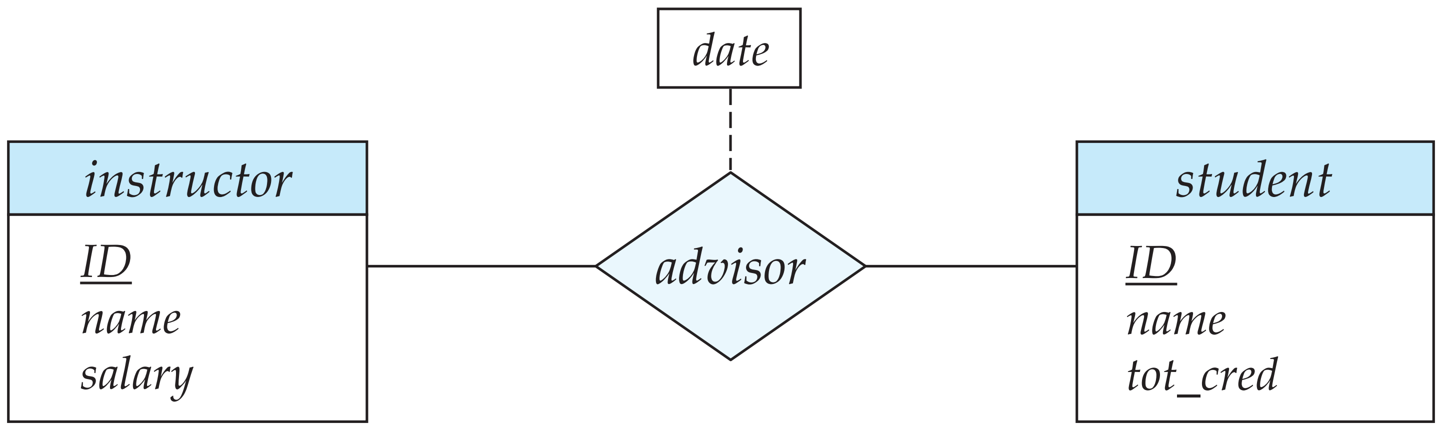


Advisor Relationship, with and without attributes

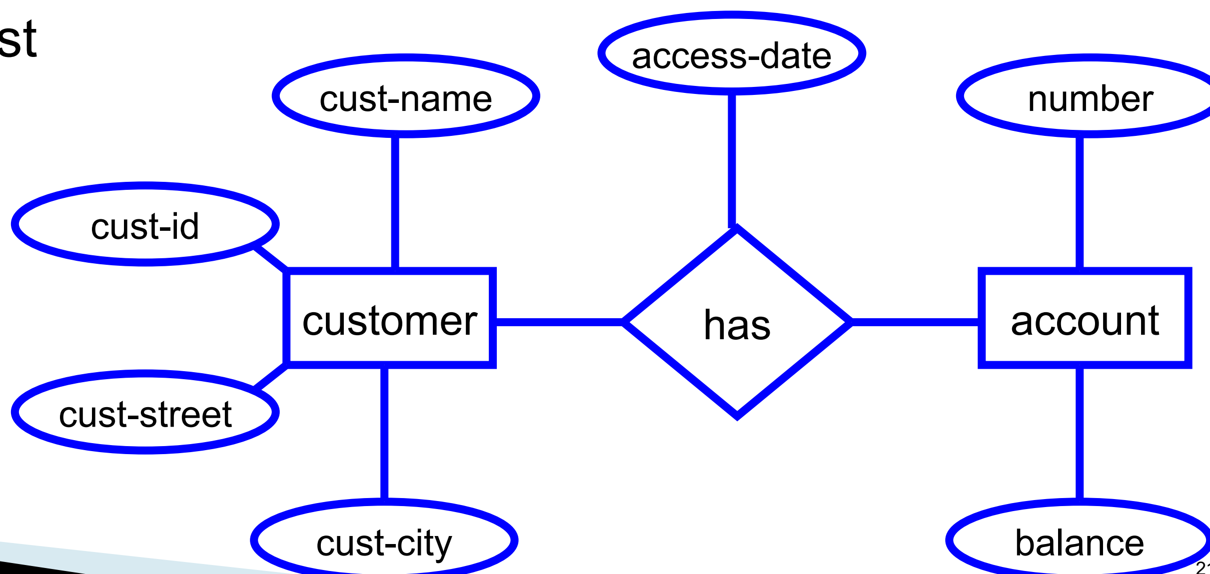




ER Diagram



Alternative representation,
used in the book in the past



Both notations used commonly

Rest of the class

- Details of the ER Model
  - How to represent various types of constraints/semantic information etc.
- Design issues
- A detailed example

Next: Relationship Cardinalities

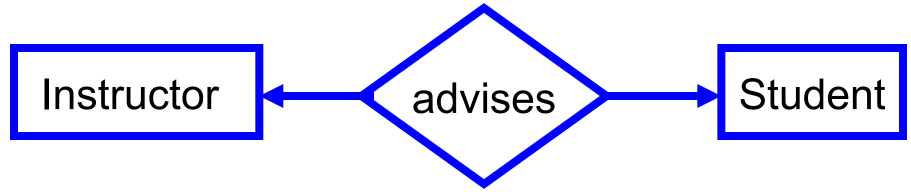
- We may know:
  - One customer can only open one account
  - OR
  - One customer can open multiple accounts
- Representing this is important
- Why ?
  - Better manipulation of data
    - If former, can store the account info in the customer table
  - Can enforce such a constraint
    - Application logic will have to do it; NOT GOOD
  - Remember: If not represented in conceptual model, the domain knowledge may be lost

Mapping Cardinalities

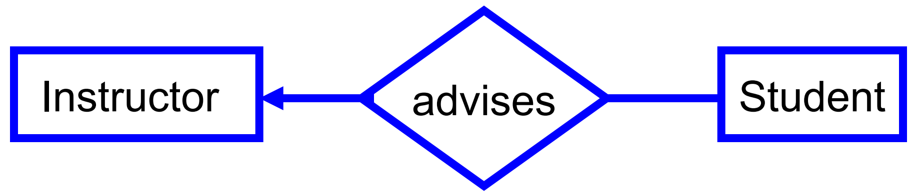
- Express the number of entities to which another entity can be associated via a relationship set
- Most useful in describing binary relationship sets

Mapping Cardinalities

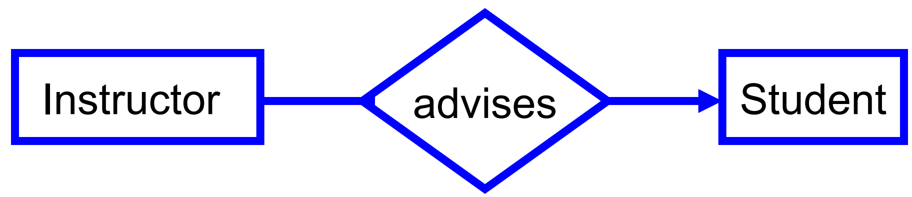
- One-to-One



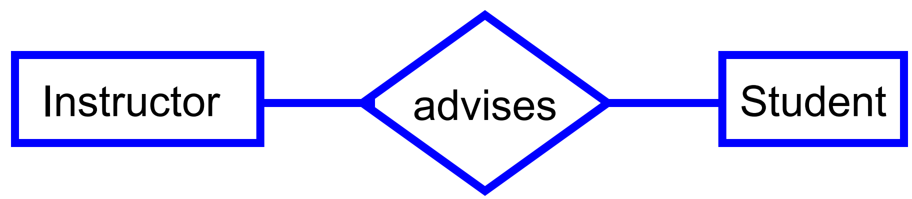
- One-to-Many



- Many-to-One



- Many-to-Many



Mapping Cardinalities

- Express the number of entities to which another entity can be associated via a relationship set
- Most useful in describing binary relationship sets
- N-ary relationships ?
  - More complicated
  - Details in the book

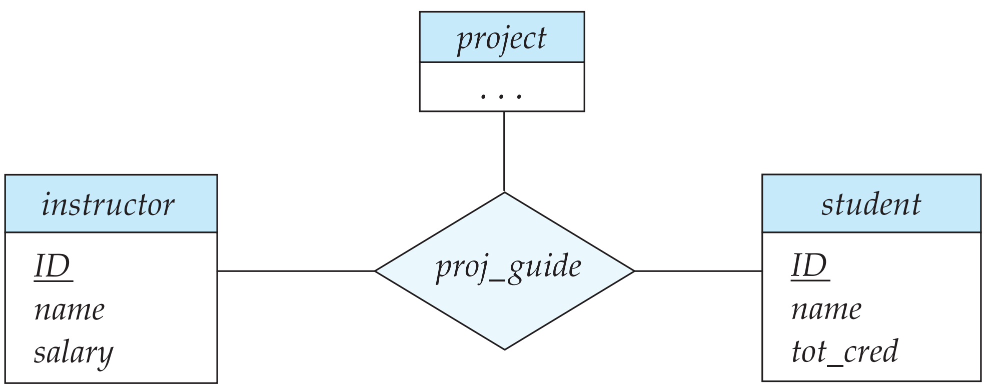
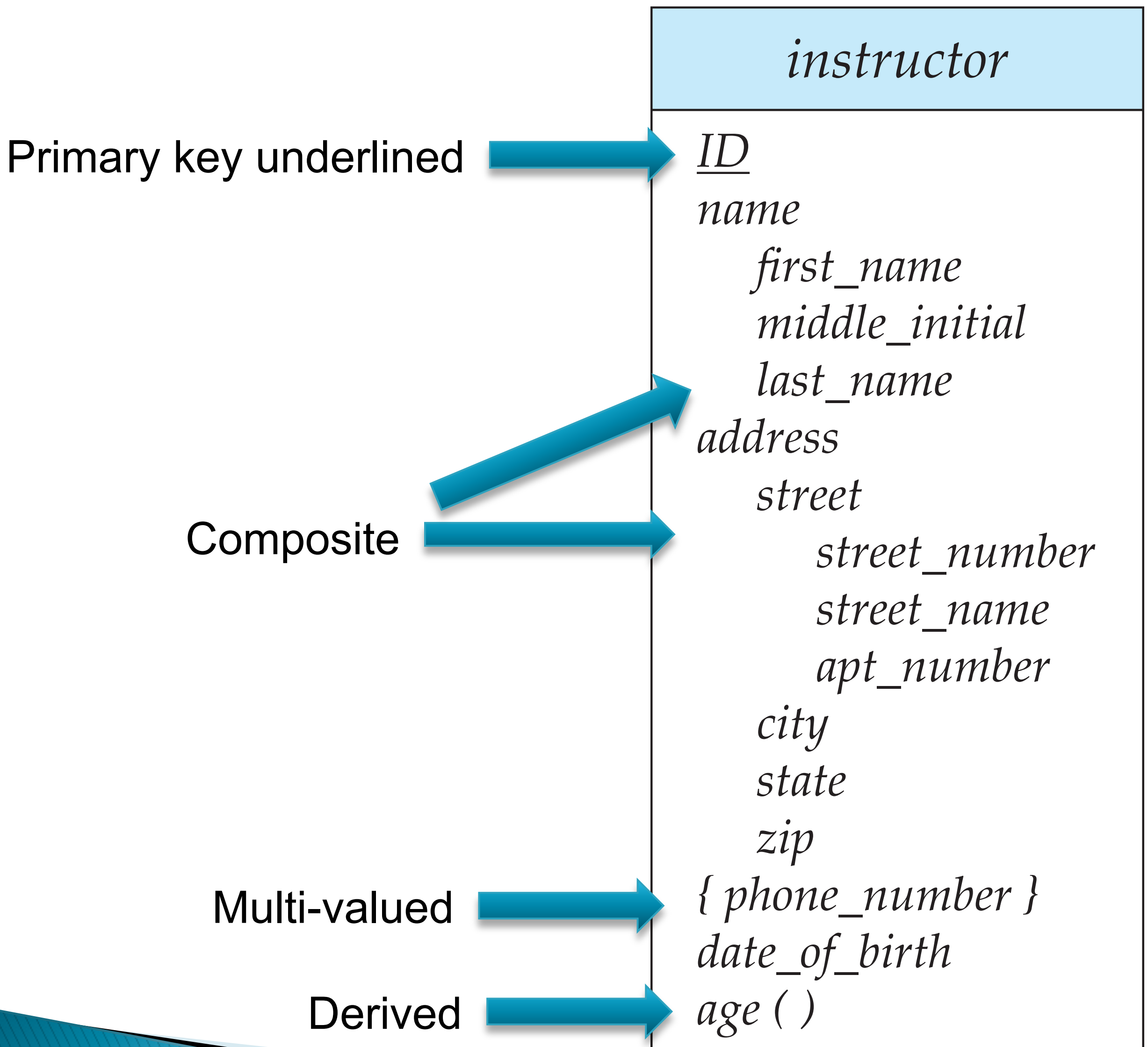


Figure 7.13 E-R diagram with a ternary relationship.

Next: Types of Attributes

- Simple vs Composite
  - Single value per attribute ?
- Single-valued vs Multi-valued
  - E.g. Phone numbers are multi-valued
- Derived
  - If date-of-birth is present, age can be derived
  - Can help in avoiding redundancy, enforcing constraints etc…

Types of Attributes



Relationship Set Keys

- What attributes are needed to represent a relationship completely and uniquely ?
  - Union of primary keys of the entities involved, and relationship attributes

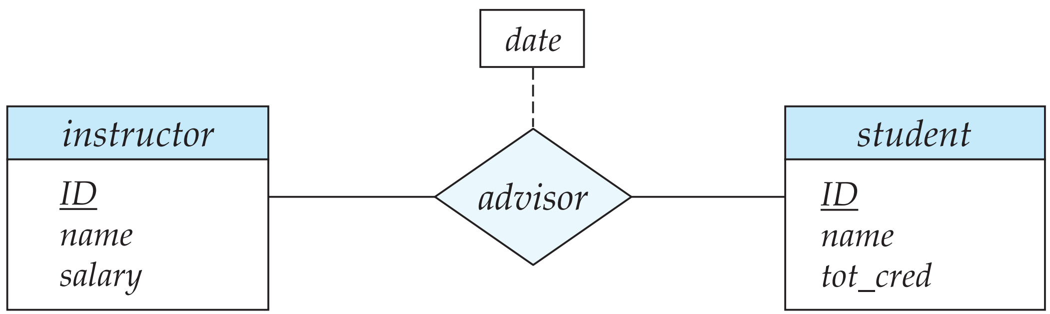


Figure 7.8 E-R diagram with an attribute attached to a relationship set.

  - {instructor.ID, date, student.ID} describes a relationship completely

Relationship Set Keys

- Is *{student_id, date, instructor_id}* a candidate key ?
  - No. Attribute *date* can be removed from this set without losing key-ness
  - In fact, union of primary keys of associated entities is always a superkey

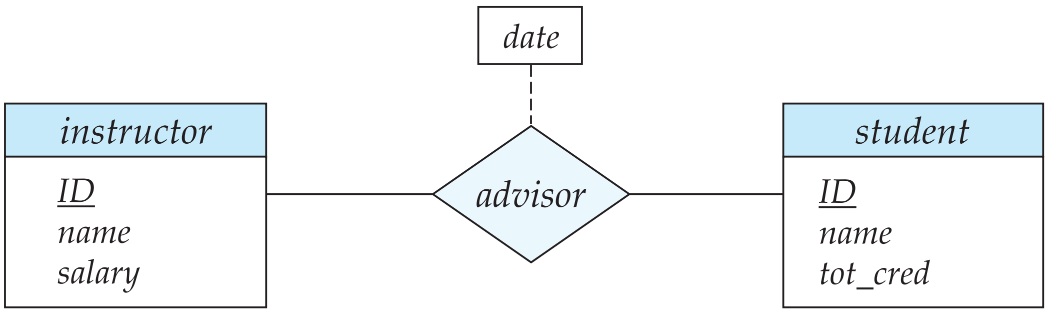


Figure 7.8 E-R diagram with an attribute attached to a relationship set.

Relationship Set Keys

- Is {student_id, instructor_id} a candidate key ?
  - Depends

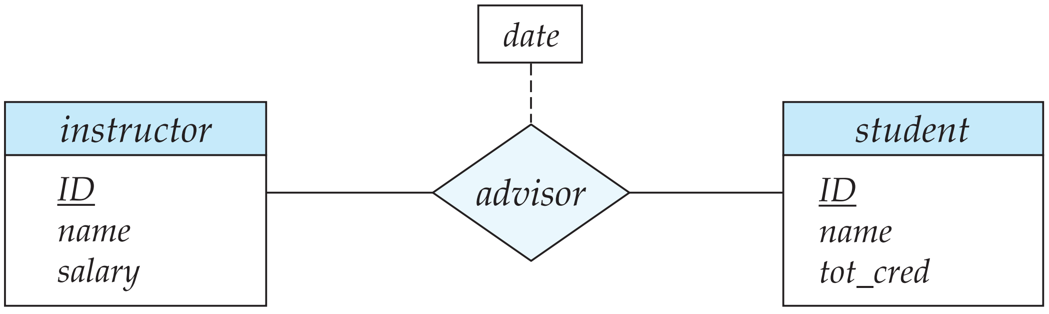


Figure 7.8 E-R diagram with an attribute attached to a relationship set.

Relationship Set Keys

- Is {student_id, instructor_id} a candidate key ?
  - Depends

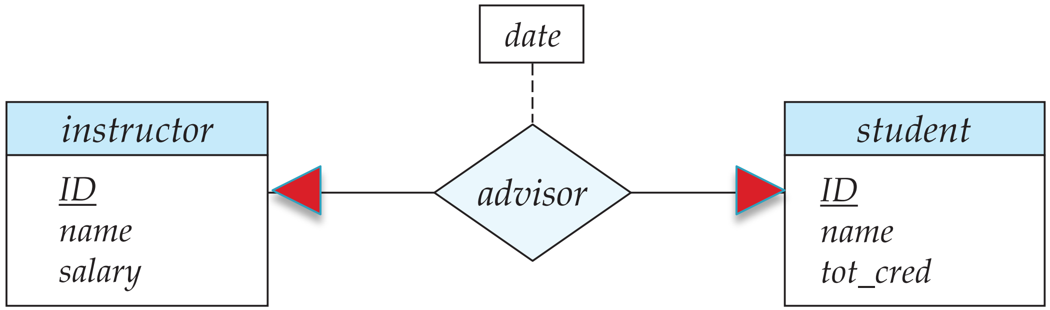


Figure 7.8 E-R diagram with an attribute attached to a relationship set.

- If one-to-one relationship, either *{instructor_id}* or *{student_id}* sufficient
  - Since a given *instructor* can only have one *advisee*, an instructor entity can only participate in one relationship
  - Ditto *student*

Relationship Set Keys

- Is {student_id, instructor_id} a candidate key ?
  - Depends

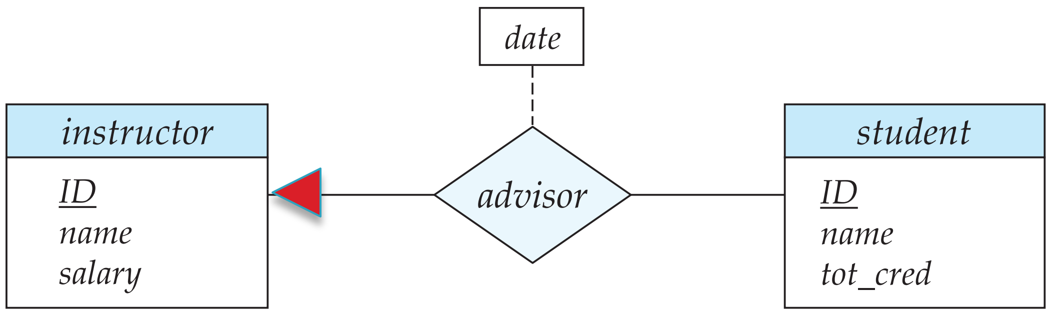


Figure 7.8 E-R diagram with an attribute attached to a relationship set.

- If one-to-many relationship (as shown), *{student_id}* is a candidate key
  - A given instructor can have many advisees, but at most one advisor per student allowed

Relationship Set Keys

- General rule for binary relationships
  - one-to-one: primary key of either entity set
  - one-to-many: primary key of the entity set on the many side
  - many-to-many: union of primary keys of the associate entity sets
- n-ary relationships
  - More complicated rules

…

- What have we been doing

- Why ?

- Understanding this is important
  - Rest are details !!
  - That’s what books/manuals are for.

Recursive Relationships

- Sometimes a relationship associates an entity set to itself
- Need "roles" to distinguish