The Relational Data Model

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Lecturer: Dr Hui Ma

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VICTORIA
UNIVERSITY OF WELLINGTON

slides by: Pavle Mogin & Hui Ma

Outline

- Basic terms and concepts:
  - Relation Schema, Attribute, Domain
  - Relation, Tuple
  - Relational database schema
  - Relational database instance
- Relational integrition constraints
  - Domain constraints, Attribute constraints
  - Key constraint, Unique constraint
  - Interrelation constraints
- Constraint violation: database updates
- Reading: Chapter of the Relational Data Model

Pre-Relational Database Systems

- Network and hierarchical database systems
  - Emerged in late sixties of the twentieth century
- Deficiencies from the network and hierarchical database systems:
  - Complex data structures (hence hard to comprehend and use),
  - No separation between logical and physical data description (hence program data dependency)
  - Navigational programming languages (low programming productivity)

The Relational Model of Data

- Introduced in 1970 by E. F. Codd
- Provides a very simple way of storing, manipulating and retrieving information
- The relational data model (RDM) represents the database as a collection of relations
- Finite relations in the mathematical sense are sets of tuples (or records)
- Well-defined concepts and easy to understand
- Clear separation of the (syntactical) schema level and the (semantic) instance level

The Relational Model of Data

- The use of relations enables a purely logical treatment of data management tasks
- The use of relations enables physical data independence
  - All physical structure concepts (storage extents, pointers, entry point records, hashing algorithms, access tree structures etc.) are hidden from users and programmers
- Declarative language for database querying and updating
- The RDM is the de facto standard for commercial database systems

Relation Schema

- A Relation Schema is denoted by $N(A_1, A_2, ..., A_n)$
  - N is the name of the relation
  - $A_1, A_2, ..., A_n$ are the attributes of the relation
- Each attribute has a domain D or a set of valid values
- The degree (or arity) of the relation is the number of attributes n of relation schema N
- **Example**: SUPPLIER (Supplier_no, Name, Address)
  - SUPPLIER is the relation name
  - Defined over the three attributes: Supplier_no, Name, Address, i.e. $n=3$

Attribute

- A property of a set of similar UoD objects, e.g.
  - Id, Fname, Dept, (semantically defined attributes)
  - $A, B, \ldots, X, Y$ (semantically un-interpreted attributes)

- The attribute name is used to interpret the meaning of the data elements corresponding to that attribute

- Some notational conventions
  - {Fname + Lname, Fname + Major } instead of {{Fname, Lname }, {Fname, Major }}

Domain

- Domain is a set of values, e.g. *STRING*, *DATE*
- It can be defined by type specification

$$D = \{d_i \mid i = 1, \ldots, n\}$$

with D as domain name and d_i as a domain element that satisfies a constraint

- Example:

CourseIdDom = {'SWEN304', 'MATH114', 'STAT193',...}

// set of character strings starting by four capital letters followed by three digits,

- There is a domain D associated with each attribute A, denoted by $dom(A) = D$
- Example: dom (Lname) = *STRING*,

dom (Course_id) = *CourseIdDom*

Tuple

- A tuple t over a relation schema $N(A_1, A_2, ..., A_n)$ is an ordered list of values, denoted
  - $t = <v_1,..., v_n>$ or $t = (v_1,..., v_n)$
- Each value is derived from an appropriate *domain* or is a *null* value (ω).
- Example:
  - t = <247, `Feed The Crowds', `Bumpytown'>
  - a tuple (row) in the SUPPLIER relation
  - this is called a 3-tuple as it has 3 values
- Tuple t is also sometime represented as
  - $t = \{(A_1,v_1),..., (A_n,v_n)\}$

  with (A_n,v_n) as (attribute, value) pairs

Relation

- Let $R = \{A_1, \ldots, A_n\}$ be a set of attributes and $dom(A_i) = D_i$, $i = 1, \ldots, n$,
- a relation r over R is a finite set of (n-)tuples t_i,

$$r = \{t_1, \ldots, t_n\}$$

t

STUDENT			
Id	**Lname**	**Fname**	**Major**
300111	Smith	Susan	COMP
300121	Bond	James	MATH
300132	Smith	Susan	COMP

- It is common to use table notation for relations,
  - the attributes of R correspond to the column heads
  - the n-tuple correspond to the rows
  - the order of the rows in such a table is not important

Relation Schema and Its Instances

- A relation is an instance of the relation schema $N(A_1, \ldots, A_n)$, denoted by $r(N)$, or simply r if it satisfies all constraints of N

- A relational variable $\rho(N)$ of the type N is the place holder of relation $r(N)$
  - The relational variable $\rho(N)$ (denoted in sequel and SQL simply by N) contains an instance of the relation schema N in each moment of time
  - It is the current instance of our relation schema $N(A_1, \ldots, A_n)$ in the database

Relation Schema, Variable, and Instances

- **Relation Schema*:***

  STUDENT(Lname, Fname, Id, Major)

  - *dom*(Lname) = *STRING*, *dom*(Fname) = *STRING*
  - *dom*(Id) = *STRING*, *dom*(Major) = *STRING*

- **Instances:**

ρ(STUDENT) at time 1			
Id	**Lname**	**Fname**	**Major**
300111	Smith	Susan	COMP
300121	Bond	James	MATH
300132	Smith	Susan	COMP

ρ(STUDENT) at time 2			
Id	**Lname**	**Fname**	**Major**
300111	Smith	Susan	COMP
300121	Bond	James	MATH
300132	Smith	Susan	COMP
300135	John	Cecil	MATH

Questions

1. Suppose you are given a set of tuples, $\{t_1, t_2, t_3\}$, where each t_i is a tuple over the same set of attributes R
   - How many different relations over R can be built by using subsets of this set of tuples?
2. Suppose you are given a set of 100 tuples over the same set of attributes R
   - How many different relations over R can be built by using subsets of this set of tuples?

Restrictions

- Let $R = \{A_1, \ldots, A_n\}$ be the set of attributes of a relation schema N and $r(N) = \{t_1, \ldots, t_n\}$
- Restriction of a tuple t onto $\{A_k, \ldots, A_m\} \subseteq \{A_1, \ldots, A_n\}$, denoted as $t[A_k, \ldots, A_m]$, refers to a sublist of values $(v_k, \ldots, v_m)$ in $t = (v_1, \ldots, v_n)$, for $1 \leq k$ and $m \leq n$
- Example: STUDENT = {Id, Lname, Fname, Major}

  t = (300121, Bond, James, MATH)

  t [*Lname*] = <Bond>,

  t [Fname, Major] = <James, Math>
- Restriction of a relation r onto a set of attributes $\{A_k, \ldots, A_m\}$, is denoted by

$$r(N)[A_k, \ldots, A_m] = \{t[A_k, \ldots, A_m] \mid t \in r\}$$

A Question

- Given a relation

STUDENT			
Id	**Lname**	**Fname**	**Major**
300111	Smith	Susan	COMP
300121	Bond	James	MATH
300132	Smith	Susan	COMP
300135	John	Cecil	MATH

- What is r(STUDENT)[Lname, Major]?

a)

Lname	Major
Smith	COMP
Bond	MATH
Smith	COMP
John	MATH

b)

Lname	Major
Bond	MATH
Smith	COMP
John	MATH

c)

Lname	Major
Smith	COMP
Bond	MATH
John	MATH

Definition Summary

- Given a relation schema $R(A_1:D_1, A_2: D_2, ..., A_n: D_n)$
  - R is the **name** of the relation
  - $A_1, A_2, ..., A_n$ are the **attributes** of the relation
  - D_i is the **domain** of attribute A_i, $dom\ (A_i) = D_i$
- For convenience we sometimes omit the domain assignment from a relation schema
- Relation $r(R)$: a specific **state** (or "value" or "population") of R is a *set of tuples* (rows)
  - $r(R) = \{t_1, t_2, \ ..., \ t_n\}$ where each t_i is an n-tuple
  - $t_i = <v_1, v_2, \ ..., \ v_n>$ where each v_j is *element-of* $dom(A_j)$
- $r(R) \subset dom\ (A_1)\ X\ dom\ (A_2)\ X\ ....X\ dom(A_n)$

Example

- Let $R(A_1, A_2)$ be a relation schema:
- Let $dom(A_1) = \{0,1\}$, $dom(A_2) = \{a,b,c\}$
- Then: $dom(A_1)$ X $dom(A_2)$ is all possible combinations:

  {<0,a> , <0,b> , <0,c>, <1,a>, <1,b>, <1,c> }
- The relation state $r(R) \subset dom(A_1)$ X $dom(A_2)$
- Example: $r(R)$ could be {<0,a> , <0,b> , <1,c> }
  - this is one possible state (or "population" or "extension") r of the relation R, defined over A_1 and A_2
  - It has three 2-tuples: <0,a> , <0,b> , <1,c>
  - How many different states (instances) can be?

Exercises

- Consider schema STUDENT(Id, Lname, Fname, Major)

1. Suppose each attribute (e.g. Lname) can get 100 different values

   a) How many different individual records of the STUDENT schema construct (e.g. (007007, Bond, James, Comp), or (010101, Wong, Sue, Math), or (007007, Mogin, Pavle, Comm)) can be made?

   b) How many different student records can be made if we introduce a constraint that each student record has to possess a unique *Id* value?

2. Suppose each attribute (e.g. Lname) can get only 2 different values, and there is no restriction on *Id* values

   c) How many different sets of records (instances) can be made?

Constraints

- Constraints are **conditions** that must hold on **all** valid relation states
- Fundamental to databases
- Real world has constraints on what is possible
- A database is an abstraction of the real world
  $\Rightarrow$ should reflect these constraints
- We cannot ensure that the database is correct, but we can ensure that it is meaningful
- Constraints are derived from the semantics of the UoD (rules of behaviour, business rules)

Relation Schema Constraints

- The basic relation schema constraints are:
  - Domain constraint
  - Attribute constraint
  - Key constraint, entity integrity constraint
  - Unique constraint
  - Referential integrity constraint
- Some other relational data model constraints, like data dependencies, e.g. functional dependencies, will be covered later in the course

Domain Constraint

- Specification of a domain:

  Domain_Name(*Basic data type*, *Maximum length*, *Condition* (*range of values* | *format*))

- e.g. *Age* (*Integer*, $0 \leq d$ and $d < 150$)
  - Domain name: *Age*
  - Basic data type: *Integer*
  - Maximum length: *not applicable*
  - Condition: $0 \leq d$ and $d < 150$ (range of values)
- e.g. *Phone* (*Char*, 12, (*999*) *999-999*)
  - Domain name: *Phone*
  - Basic data type: *Char*
  - Maximal length: *12*
  - Condition: (*999*) *999-999* (format)

Attribute Constraint

- Domain constraints restrict the attribute values, but may not be sufficient
- Attribute constraints can further restrict attribute values
- Generally, the attribute constraint of an attribute A within a relation schema N is defined as

$$(Dom(N, A), Range(N, A), Null(N, A))$$

  - $Dom(N, A)$ associates attribute A in N with a domain via domain name D
  - $Range(N, A)$ is used to further restrict the range of allowable attribute A values in the relations over N
  - $Null(N, A)$ specifies whether attribute A may or may not have a null value in any instance over N

Attribute Constraint Examples

- Relation schema: STUDENT
  - Attribute: FName
  - *Dom*(STUDENT, Fname) = *STRING*
  - *Range*(STUDENT, Fname) = *none*
  - *Null*(STUDENT, Fname) = N //*not null*

- Relation schema: GRADES
  - Attribute: Grade
  - *Dom*(GRADES, Grade) = *STRING*
  - *Range*(GRADES, Grade): one of {'A+', 'A', 'A-', 'B+', 'B', 'B-', 'C+', 'C'}
  - *Null*(GRADES, Grade) = Y //*yes, null value allowed*

Relation Schema Key

- A relation is a set of tuples, hence all tuples have to be distinct
- Let $N(A_1,\ldots, A_n)$ be a relation schema and $X = \{A_k,\ldots, A_m\} \subseteq \{A_1,\ldots, A_n\}$, X is a relation schema key of N, if

$1^o\ (\forall r(N))(\forall u, v \in r(N))(u[X] = v[X] \Rightarrow u = v)$ (unique)

$2^o\ (\forall Y \subset X)(\neg 1^o)$ (minimal)

$3^o\ (\forall r(N))(\forall t \in r(N))(\forall A \in X)(t[A] \neq \omega)$ (not null)

- A relation schema key is not allowed to have a null value as the key value is used to identify the individual tuples.
- A relation schema key is also called a minimal key or a key

Primary Key and Entity Integrity

- A relation schema may have more than one key K
- One of the relation schema keys K is designated as a primary key denoted by K_p
  - a key used in UoD for identification most frequently
- Entity integrity constraint: no primary key values can be null
- Examples:
  - STAFF(IRDNo, Staff_id, Fname, Lname, DoB)
    - K = {IRDNo, Staff_id }
    - K_p = {Staff_id}
  - STUDETNT(Id, Fname, Lname, Major) (the primary key is underlined)

Superkey, Unique Constraint

- A superkey is a superset of a minimal key

$1^o\ (\forall r\ (N\ ))(\forall u, v \in r\ (N\ ))(u\ [X\ ] = v\ [X\ ] \Rightarrow u\ = v\ )$ (unique)

$3^o\ (\forall r\ (N\ ))(\forall t \in r\ (N\ ))(\forall A \in X\ )(t\ [A\ ] \neq \omega)$ (not null)

- A unique constraint is a constraint that satisfies the condition

$1^o\ (\forall r\ (N\ ))(\forall u, v \in r\ (N\ ))(u\ [X\ ] = v\ [X\ ] \Rightarrow u\ = v\ )$ (unique)

  - Can be null
  - May not minimal (but it is preferred to make it minimal)

Example

- Consider the relation GRADES
- Suppose for each course a student may have **at most one** grade. What is the relation scheme key?

GRADES		
Id	**Course_id**	**Grade**
300111	SWEN304	A+
300111	COMP301	A
300111	MATH314	A
300121	COMP301	B
300132	COMP301	C
300121	SWEN304	ω
300132	SWEN304	ω

Example

- Consider the relation GRADES
- Suppose for each course a student may have **more than one** grade, but **at most one** in a given term. What is the relation scheme key?

GRADES			
Id	**Course_id**	**Term**	**Grade**
300111	SWEN304	1501	A+
300111	COMP301	1501	A
300111	MATH214	1602	A
300121	COMP301	1502	B
300111	MATH214	1502	D
300132	COMP301	1602	C
300121	SWEN304	1602	B
300132	MATH214	1702	ω

An Example: Inconsistent Relations

STUDENT			
Id	**Lname**	**Fname**	**Major**
300111	Smith	Susan	COMP
300121	Bond	James	MATH
300132	Smith	Susan	COMP
300132	John	Cecil	MATH

COURSE			
Course_id	**Cname**	**Points**	**Dept**
SWEN304	DB sys	15	Engineering
COMP301	softEng	20	Engineering
COMP301	softDesign	20	Engineering
MATH214	DisMat	15	Mathematics

Redefining Some Terms

- Relation schema $N(R, C)$
  - N is the name, R is the set of attributes, C is the set of constraints

- A tuple t over R:
  - the set of pairs $t = \{(A_1, a_1), \ldots, (A_n, a_n)\}$, where $A_i \in R$, $a_i \in dom(A_i)$, and $n = |R|$ is $Degree(r(N))$

- Relation schema instance (relation) $r(N)$ over R:
  - a finite set of n-tuples that satisfies all constraints

Relational Databases

- A single relation is not adequate for many database applications
  - "Flat-file" databases are single relation schema databases.
- Typically, we need many relation schemas
  - for each kind of entity we are interested in
  - for each interaction/relationship between kinds of entities
  - for multi-valued properties of entities
- Need to connect the relation schemas
  - "Foreign keys"
- Need to ensure integrity of the whole database
  - "Referential Integrity" constraints

Relational Database Schema

- Relational database schema $N(S, IC)$
  - N is the name,
  - $S = \{N_1(R_1, C_1), \ldots, N_k(R_k, C_k)\}$ is a set of relation schemas, and
  - IC is a set of interrelation constraints
- Example:
  - Name N = UNIVERSITY
  - The set of relation schemas

S = {STUDENT({Id, FName, LName, Major }, {Id}),
GRADES({Id, Course_id, Grade }, {Id + Course_id}),
COURSE({Pname, Points, Course_id, Dept }, {Course_id})}

Foreign Key

- Relation schemas are connected to each other by (primary key, foreign key) pairs
- Example:

  TEXTBOOK({Title, ISBN, Pcode, Pnum }, {ISBN })

  COURSE({Pcode, Pnum, Pname }, {Pcode + Pnum })
- Instances are connected by (*primary key*, *foreign key*) values
- A foreign key may contain null value

TEXTBOOK			
Title	**ISBN**	**Pcod**	**Pnum**
COD	1111	COMP	203
FDBS	2222	SWEN	ω

COURSE		
Pcode	**Pnum**	**Pname**
COMP	203	CO
SWEN	304	DBS

Foreign Key (A General Definition)

- Let $X = \{A_1,\ldots, A_m\}$ be the primary key of $N_1(R_1, C_1)$, and let $Y = \{B_1,\ldots, B_m\}$ be a subset of R_2 in $N_2(R_2, C_2)$

- $Y = \{B_1,\ldots, B_m\}$ is a foreign key in $N_2(R_2, C_2)$ with regard to X in N_1, if:
  - $(\forall i \in \{1,\ldots, m\})(Dom(N_2, B_i) \subseteq Dom(N_1, A_i))$ (Domain compatibility),
  - $(\forall i \in \{1,\ldots, m\})(Range(N_2, B_i) \Rightarrow Range(N_1, A_i))$ (Attribute compatibility)

Referential Integrity

- Referential integrity is also called a foreign key constraint, denoted as

$$N_2[Y] \subseteq N_1[X] \text{ or } N_2.Y < N_1.X$$

- Relations $r(N_2)$ and $r(N_1)$ satisfy referential integrity $N_2[Y] \subseteq N_1[X]$ if the set of **not null** elements of the restriction $r(N_2)[Y]$ is contained in the restriction $r(N_1)[X]$
  - N_2: the referencing relation schema
  - N_1: the referenced relation schema
- It is used to maintain consistency among tuples of two relations, connected by a (*primary key*, *foreign key*) pair

Referential Integrity – A Formal Definition

- Relations $r(N_2)$ and $r(N_1)$ satisfy referential integrity $N_2[Y] \subseteq N_1[X]$ if

$$(\forall u \in r(N_2))(\exists v \in r(N_1))(u[Y] = v[X] \vee (\exists i \in \{1, \ldots, m\})(u[B_i] = \omega))$$

- Either tuples u and v are equal on X and Y values, or there exists at least one attribute in Y whose u value is null

Referential Integrity Constraints

- A set of referential integrity constraints forms the most important subset of the relational database schema constraints set IC.
- Very often, referential integrities are the only interrelation constraints considered
- Example
  - Database schema name: UNIVERSITY
  - A set of relation schemas:

$$S = \{\text{STUDENT, GRADES, COURSE}\}$$

$$IC = \{\text{GRADES[Id]} \subseteq \text{STUDENT[Id]},$$
$$\text{GRADES[Course\_id]} \subseteq \text{COURSE[Course\_id]} \}$$

An Example – Consistent relations

STUDENT			
Id	**Lname**	**Fname**	**Major**
300111	Smith	Susan	COMP
300121	Bond	James	MATH
300143	Bond	Jenny	MATH
300132	Smith	Susan	COMP

COURSE			
Course_id	**Cname**	**Points**	**Dept**
SWEN304	DB sys	15	Engineering
COMP301	softEng	20	Engineering
MATH214	DisMat	15	Mathematics

GRADES[Id] ⊆ STUDENT[Id]

GRADES[Course_id] ⊆ COURSE[Course_id]

GRADES		
Id	**Course_id**	**Grade**
300111	SWEN304	A+
300111	COMP301	A
300111	MATH214	A
300121	COMP301	B
300132	COMP301	C
300121	SWEN304	B+
300132	SWEN304	C+

An Example – Inconsistent relations

STUDENT			
Id	**Lname**	**Fname**	**Major**
300111	Smith	Susan	COMP
300121	Bond	James	MATH
300143	Bond	Jenny	
300132	Smith	Susan	COMP

COURSE			
Course_id	**Cname**	**Points**	**Dept**
SWEN304	DB sys	15	Engineering
COMP301	softEng	20	Engineering
MATH214	DisMat	15	Mathematics

GRADES		
Id	**Course_id**	**Grade**
300111	SWEN304	A+
300111	COMP301	A
300111	MATH114	A
300121	COMP301	B
300132	COMP301	C
300121	SWEN304	B+
300138	SWEN304	C+

- To avoid inconsistencies with reality we first need to observe the data dependencies hold in reality and make them explicit (specify them)

A Common Pitfall – Foreign key

- Consider the following relation schemas:

  PERSON({Name, Birthday, Address}, {Name + Birthday})

  STUDENT({ID, Name, Birthday}, {ID})

- We define a foreign key on STUDENT:

  $STUDENT[Name, Birthday] \subseteq PERSON[Name, Birthday]$

- This is **NOT equivalent** to: (Why?)

  $STUDENT[Name] \subseteq PERSON[Name]$, and

  $STUDENT[Birthday] \subseteq PERSON[Birthday]$

PERSON		
Name	Birthday	Address
Grampa Simpson	01.01.1900	16 Park Ave
Apu Nahasapeemapetilon	29.02.1961	98 Ada St.

STUDENT		
ID	Name	Birthday
007	Apu Nahasapeemapetilon	01.01.1900
008	Grampa Simpson	29.02.1961

Other Types of Constraints

- Semantic Integrity Constraints:
  - based on application semantics and cannot be expressed by the model per se
  - Example: "the max number of courses a student can enroll in one year"
- A **constraint specification** language may have to be used to express these
- SQL-99 allows triggers and ASSERTIONS to express for some of these

Relational Database Instance

- A database schema *DBS* as a complex data type defines a finite, but very large number of different database instances
- An instance of the relational database schema $N(S, IC)$ is

$$db = \{r(N_1), \ldots, r(N_k)\}$$

such that:

- Each $r(N)$ is an instance of a relation schema $N(R, C)$ in S, and
- db satisfies all constraints in IC

Relational Database Instance

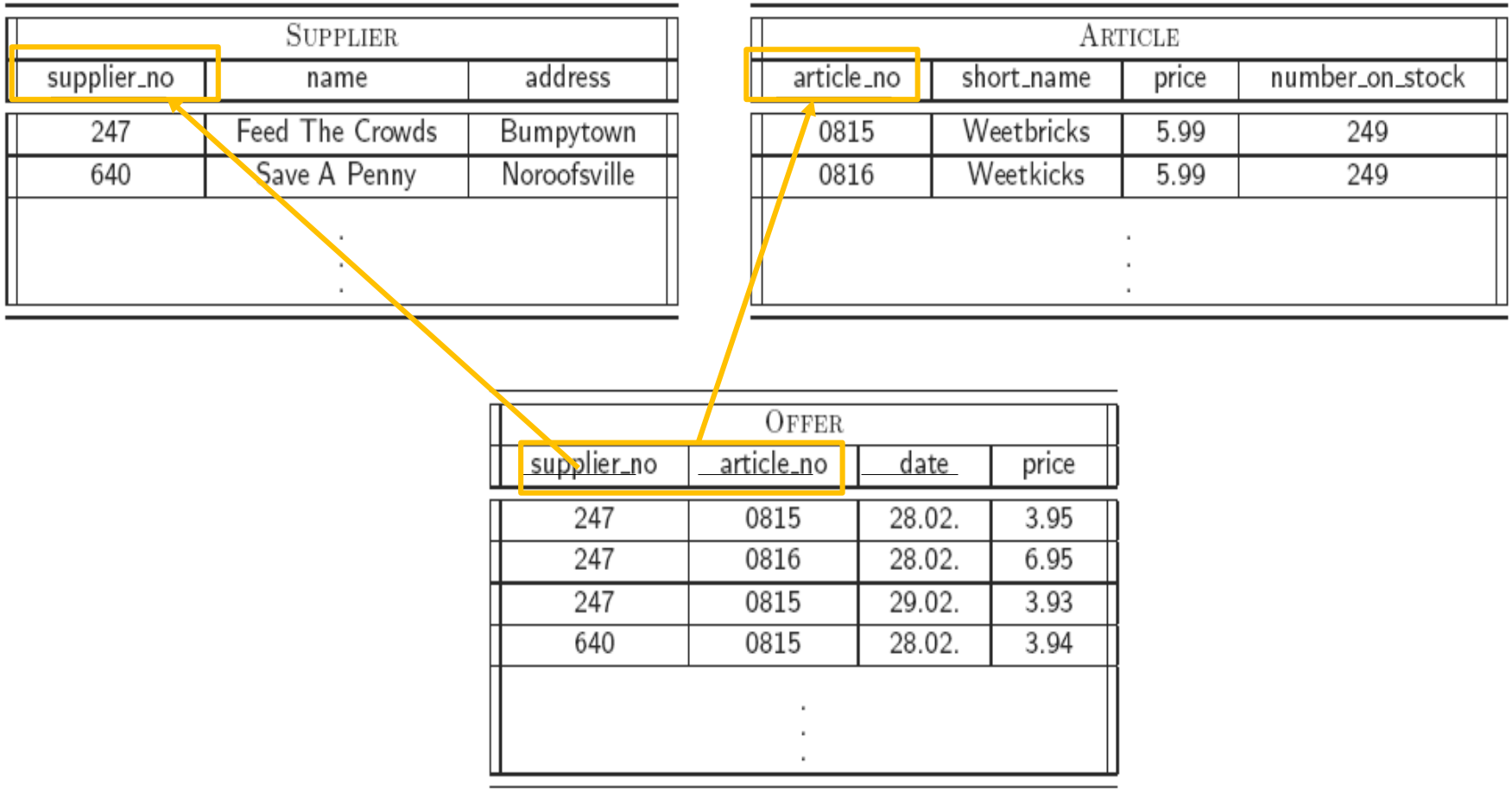
- A database variable dbs of the type DBS contains a set of relational variables $\{\rho(N_1),\ldots,\rho(N_k)\}$
- A relational variable $\rho(N_1)$ contains an instance of the relation schema N in each moment of time
- In the sequel
  - a database variable has the same name as the database schema itself
  - each relation variable has the same name as the corresponding relation schema

Database Schema and Its Instances

- Example:
  - N = BOOKSHOP
- S = {SUPPLIER(supplier_no, name, address),
  ARTICLE(article_no, short_name, number_on_stock, price),
  OFFER(supplier_no, article_no, date, price) }

- IC = { OFFER [supplier_no] $\subseteq$ SUPPLIER [supplier_no]
  OFFER [article_no] $\subseteq$ ARTICLE [article_no]}

An Instance of The BOOKSHOP Database



SUPPLIER

supplier_no	name	address
247	Feed The Crowds	Bumpytown
640	Save A Penny	Noroofsville
.	.	.

ARTICLE

article_no	short_name	price	number_on_stock
0815	Weetbricks	5.99	249
0816	Weetkicks	5.99	249
.	.	.	.

OFFER

supplier_no	article_no	date	price
247	0815	28.02.	3.95
247	0816	28.02.	6.95
247	0815	29.02.	3.93
640	0815	28.02.	3.94
.	.	.	.

Key Constraints

- You are given a relation schema $N(R, C)$ and an instance $r(N)$
- Suppose C does not contain any key specification
- Inferring keys from instances is very hard if possible at all, since there are so many of them
- By analyzing instances and $Null(N, A)$ constraints, you can only conclude which subsets of R can not be a key
- Also, from instances you may infer which key constraints are not violated by instances

Find Key Constraints not Violated in r(N)

a) Suppose $Null(N, A) = N$ for all attributes except F in N_2

$r(N_1) =$

A	B	C	D
a_1	b_1	c_1	d_1
a_2	b_2	c_2	d_2
a_3	b_3	c_3	d_3
a_4	b_3	c_4	d_3
a_5	b_1	c_5	d_3

$r(N_2) =$

A	B	C	D	E	F
a_1	b_1	c_1	d_1	e_1	f_1
a_1	b_2	c_1	d_2	e_1	f_2
a_2	b_1	c_2	d_1	e_2	f_3
a_1	b_3	c_3	d_1	e_1	ω
a_3	b_1	c_1	d_3	e_2	f_4

b) Suppose now $Null(N_1, C) = Y$ and $Null(N_2, D) = Y$ and $Null(N_2, F) = Y$, and there are some null values in the corresponding columns

Procedure

1. Produce a power set of the set of relation schema attributes
2. Check subsets for key constraint satisfaction, starting from the subsets with lower cardinality
3. If a subset satisfies a key constraint, all its supersets will also satisfy, and therefore do not need to be checked

- Results $(SatKey(N)(r\ (N))$ key constraint of relation schema N not violated in $r\ (N))$
- a):
  - $SatKey(N_1)(r(N_1)) = \{A, C\}$,
  - $SatKey(N_2)(r\ (N_2)) = \{AB, CD, BCE, BDE\ \}$
- b):
  - $SatKey(N_1)(r\ (N_1)) = \{A\}$,
  - $SatKey(N_2)(r\ (N_2)) = \{AB, BCE\ \}$

Relational Database Operations

- Database Management System must implement **update** operations:
  - insert,
  - delete, and
  - modify

- Database Management System must implement **retrieval** operations:
  - query language
  - Need a well defined language

DB Updates and Constraints

- No update operation should leave a database in an inconsistent state (with violated constraints)
- A DBMS must take the actions necessary to prevent a constraint violation:
  - **reject**: do not allow the operation
  - **cascade**: propagate the operation by making necessary consequential changes
  - **set null**, or **set default**: reset other values to maintain consistency

Inserts and Constraint Violations

- Inserting a new tuple could violate
  - Attribute/domain constraints
    (a value is not of the right type or within the required range)
  - Uniqueness constraints
    (the values of the key attributes duplicate another tuple)
  - Not Null constraints
    (an attribute has the value null when it shouldn't)
  - Referential Integrity constraints
    (the values of the attributes of a foreign key do not match any tuple in the other relation)
- Response:
  - **Reject** the operation – there is no change that the DBMS system could safely make to resolve the inconsistency

Deletes and Constraint Violations

- Deleting a tuple can only violate a referential integrity constraint:
  - If a tuple t is referred to by foreign keys in some tuples $t_1, t_2, \ldots t_n$ in other relations, then deleting t will make $t_1, t_2, \ldots t_n$ inconsistent.
  - Example:
    - Delete a student record from the database, and all their grade records will refer to nothing
- There are several options:
  - **Reject** the deletion
  - **Set null / set default**: insert null or a default value in the foreign key attributes of tuples in other relation(s) that refer to t (can't do set null if foreign key attributes are NOT NULL)
  - **Cascade**: delete tuples in other relation(s) that refer to t (appropriate only if the other tuples "existentially depend" on t)

Modify and Constraint Violations

- Modifying/updating the values of attributes in a tuple may violate constraints
  - Attribute/domain constraints
    Response: ***reject*** *(like insert)*
  - Key constraints (if attribute is part of a key)
    Response: treat as a delete followed by an insert
  - Referential integrity constraints (if attribute is part of a foreign key).
    Response: ***reject*** *(like insert), or* ***cascade****, or* ***set null,*** *or* ***set default*** *(like delete)*

A Question for You

- Consider the following database instance

TEXTBOOK			
Title	**ISBN**	**Pcode**	**Pnum**
COD	1111	COMP	203
FDBS	2222	SWEN	ω

COURSE		
Pcode	**Pnum**	**Pname**
COMP	203	CO
SWEN	304	DBS

- Should a DBMS reject the following update operation: (Y/N)?

```
UPDATE TEXTBOOK SET PNum = 304 WHERE ISBN = 2222;
```

- Should a DBMS reject the following update operation: (Y/N)?

```
UPDATE TEXTBOOK SET PNum = 304 WHERE ISBN = 1111;
```

DB Updates and Constraints

Update operation	Domain / Attribute constraint	Key / Entity integrity constraint,	Referential integrity
insert	reject	reject	reject
delete	no violation	no violation	reject, cascade, set null, set default
modify	reject	reject	reject, cascade, set null, set default

Summary

- Basic concepts of the relational data model:
  - Domain (set of values) – data type,
  - Attribute (property of a set of similar UoD objects),
  - Relation schema
- Relation schema constraints:
  - Domain constraint,
  - Attribute constraint,
  - Key constraint and unique constraint
- A **relational** database schema – a set of relation schemas and a set of interrelation constraints
- The referential integrity is the most important interrelation constraint, it links tuples of two relations
- A relational database is a set of such relation instances that satisfy all relational and interrelation constraints
- No update operation should leave a database in an inconsistent state (with violated constraints)