CSC10006 – Introduction to Database

Chapter 7
Integrity Constraint

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Content

- **Overview**
- Characteristics of Integrity Constraints
- Classification
- Implementation

Overview

- **Integrity Constraints** (IC) are discovered from the semantics of the data or the representation of the data in business(1).
- IC is to ensure (1):
  - The correctness of the data and data schema.
  - The semantic of the database schema.
- When an IC is declared, all instances of a database must satisfy the IC at any time (1).
- An IC is discovered and declared by database designer during the design phase (1).
- An IC is defined on a relational schema or involves in may relational schemas (1).

(1) *Fundamental of Databases 4th , Ramez Elmasri & Shamkant B. Navathe, ISBN 0-321-12226-7, 2003*

Content

- Overview
- **Characteristics of Integrity Constraints**
  - Context
  - Content
  - Table of influence
- Classification
- Implementation

Context

- **Context** of an IC
  - **Relation** schemas that are likely to be violated by the IC when performing **data updates** (adding, deleting, modifying data).

- Example (IC_1)
  - The salary of a lecturer cannot exceed the head of the department
    - Update operations that affect to the IC1
      - Update the salary of the lecturer
      - Add new a lecturer to department
      - Appoint a new department head
    - Context: GIAOVIEN, BOMON

Context (cont.)

- Example (IC_2)
  - The direct manager (of a lecturer) must be a lecturer in the same department
    - Update operations that affect the IC2
      - Update line manager of a lecturer
      - Add new a lecturer
    - Context: GIAOVIEN

Content

- The content of a IC is presented by:
  - Natural language
    - Easy to understand but lack of formal, consistency
  - Formal language
    - Concise, consistent but sometimes difficult to understand
    - Language forms
      - Relational Algebra
      - (Tuples) Relational Calculus
      - Pseudo Code

Content (cont.)

- Example (IC_1)
  - Natural language
    - The salary of a teacher should not surpass that of his or her department head.
  - Formal language

$$(\forall t)(GIAOVIEN(t) \wedge (\exists s)(BOMON(s) \wedge (\exists u)(GIAOVIEN(u) \wedge s.TRUONGBM = u.MAGV \wedge s.MABM = t.MABM \wedge t.LUONG \leq u.LUONG)))$$

Content (cont.)

- Example (IC_2)
  - Natural language
    - The direct supervisor of a teacher must be a teacher within the same department.
  - Formal language

$$(\forall t)(GIAOVIEN(t) \wedge (t.GVQLCM \neq null \Rightarrow (\exists s)(GIAOVIEN(s) \wedge s.MABM = t.MABM \wedge s.MAGV = t.GVQLCM)))$$

Influence Table

- Determine which update operations need to check for IC when performed on the relations context.

- 2 types
  - Influence table for 1 IC
  - Aggregate influence table for all ICs

Influence table for 1 IC

IC title	Insert	Delete	Update
Relation 1	+	–	+ (Attributes)
Relation 2	–	+	–
…			
Relation n	–	+	–

(+) Violation of IC
(–) Not violation of IC

Aggregate influence table

	IC 1			IC 2						IC m		
	T	X	S	T	X	S	…	…	…	T	X	S
Relation 1	+	-	+	+	-	+				+	-	+
Relation 2	-	+	-									
Relation 3	-	-	+							-	+	-
…												
Relation n				-	+	-				-	-	+

Content

- Overview
- Characteristics of Integrity Constraints
- **Classification**
- Implementation

IC Classification

- ICs are classified into three main categories [1]:
  - Inherent-model based constraints (RBTV bắt buộc liên quan đến mô hình dữ liệu).
    - Ex: A relation cannot contain duplicate tuples.
  - Schema-based constraints (RBTV liên quan đến lược đồ của mô hình dữ liệu).
    - Ex: Value domain constraints, key constraints, null constraints, referencial constraints.
  - Application-based constraints (RBTV dựa trên ứng dụng).
    - Ex: The salary of a lecturer cannot exceed the department head.

[1] *Fundamental of Databases 4th , Ramez Elmasri & Shamkant B. Navathe, ISBN 0-321-12226-7, 2003*

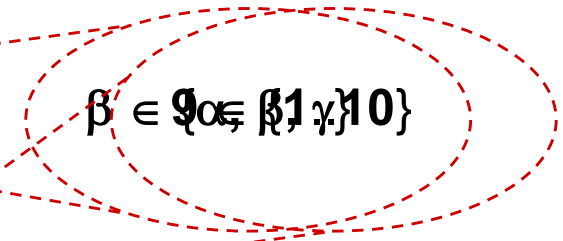
IC Classification

- IC having the context of one relation
  - Domain value (miền giá trị)
  - Multiple tuples (liên bộ)
  - Multiple attributes (liên thuộc tính)
- IC having the context of many relations
  - Reference (tham chiếu)
  - Multiple tuples through multiple relations (liên bộ liên quan hệ)
  - Multiple attributes through multiple relations (liên thuộc tính liên quan hệ)
  - Inference/calculated attributes (thuộc tính suy diễn)
  - Relations form a cycle in relation graph (chu trình)

IC - Domain Value

- Constraints specifying values for an attribute

R	A	B	C	D
	α	α	1	1
	α	β	5	7
	β	β	12	3
	β	β	23	9



- Domain value
  - Continuous (liên tục)
  - Disjointed (rời rạc)

Example 3

- Lecturer's gender must be ‘Nam’ or ‘Nữ’
  - Context: GIÁOVIÊN
  - Content:

$$(\forall t)(\text{GIAOVIEN}(t) \wedge (t.\text{PHAI} = \text{'Nam'} \vee t.\text{PHAI} = \text{‘Nữ‘}))$$

or $\text{DOM}(\text{PHAI}) = \{\text{‘Nam’}, \text{‘Nữ’}\}$

  - Influence table:

IC_3	Insert	Delete	Update
GIÁOVIÊN	+	–	+ (PHAI)

Example 4

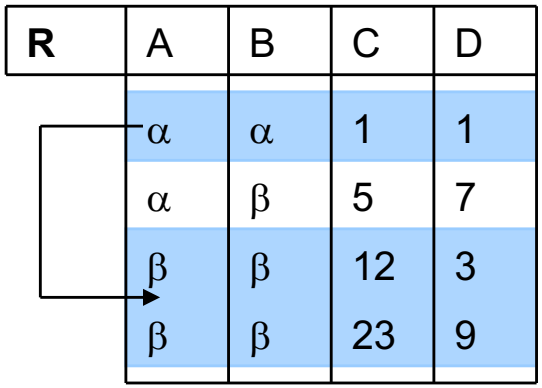
- Allowance for each work in project must not exceed 20 million VND.
  - Context: THAMGIAĐT
  - Content:

    $(\forall t)(\text{THAMGIAĐT}(t) \wedge t.\text{PHỤCẤP} \leq 20)$
  - Influence table:

IC_4	Insert	Delete	Update
THAMGIAĐT	+	–	+ (PHỤCẤP)

IC - Multiple tuples

- The existence of one or more tuples depends on the existence of one or more other tuples in the same relation



R	A	B	C	D
	α	α	1	1
	α	β	5	7
	β	β	12	3
	β	β	23	9

- Special cases
  - IC – primary key
  - IC unique (key)

Example 5

- Department name is unique.
  - Context: BOMON
  - Content:

$$(\forall t1, t2)\ (BOMON(t1) \wedge BOMON(t2) \wedge (t1 \neq t2 \Rightarrow t1.TENBM \neq t2.TENBM))$$

or

$$(\forall t1)(BOMON(t1) \wedge \neg(\exists t2)(BOMON(t2) \wedge t1 \neq t2 \wedge t1.TENBM = t2.TENBM))$$

  - Influence table:

IC_5	Insert	Delete	Update
BOMON	+	–	+ (TENBM)

Example 6

- A lecturer can participate in up to 5 works in all projects
  - Context: THAMGIAĐT
  - Content:

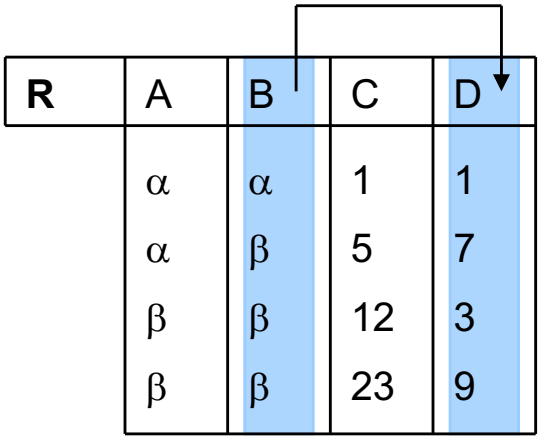
$$(\forall t)(THAMGIADT(t) \wedge card(\{ s \mid THAMGIADT(s) \wedge s.MAGV = t.MAGV\}) \leq 5)$$

  - Influence table:

IC_6	Insert	Delete	Update
THAMGIADT	+	–	+ (MAGV)

IC – Multiple attributes

- Constraint between attributes in the same relation



R	A	B	C	D
	α	α	1	1
	α	β	5	7
	β	β	12	3
	β	β	23	9

Example 8

- A lecturer must not manage him/herself (Một giáo viên không trực tiếp quản lý chuyên môn chính mình)
  - Context: GIAOVIEN
  - Content:

$$(\forall t)(\ GIAOVIEN(t) \wedge (t.GVQLCM = null \vee t.GVQLCM \neq t.MAGV)\ \}$$

  - Influence table:

IC8	Insert	Delete	Update
GIAOVIEN	+	–	+ (GVQLCM)

Example 9

- The start date of a project is always smaller than the end date.
  - Context: ĐỀTÀI
  - Content:

$$(\forall t)(\text{ĐỀTÀI}(t) \wedge t.\text{NGÀYBĐ} \leq t.\text{NGÀYKT})$$

  - Influence table:

IC9	Insert	Delete	Update
ĐỀTÀI	+	–	+ (NGÀYBĐ, NGÀYKT)

Example 10

- The start date of a work is always smaller than the end date of that work.
  - Context: CÔNGVIỆC
  - Content:

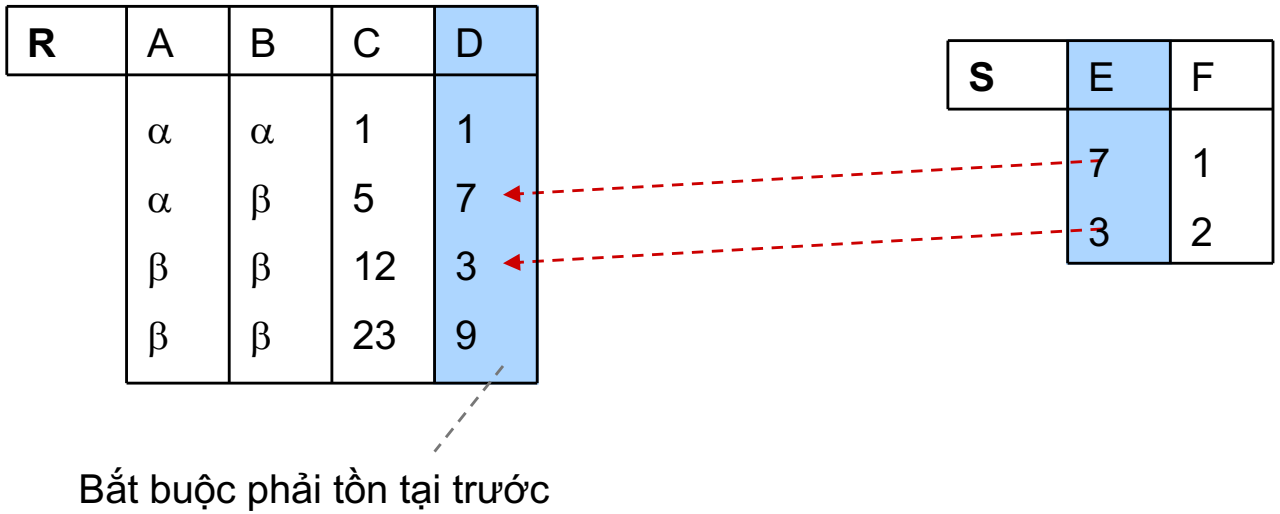
$$(\forall t)(\text{CÔNGVIỆC}(t) \wedge t.\text{NGÀYBĐ} \leq t.\text{NGÀYKT})$$

  - Influence table:

IC_{10}	Insert	Delete	Update
CÔNGVIỆC	+	–	+ (NGÀYBĐ, NGÀYKT)

IC - Reference

- Values of attributes in a relation must refer to the values of attributes in other relation.



- Special case
  - IC foreign key

Example 11

- Every lecturer must belong to/work in a department.
  - Context: BOMON, GIAOVIEN
  - Content:

$$(\forall t)(GIAOVIEN(t) \wedge (\exists s)(BOMON(s) \wedge s.MABM = t.MABM))$$

  - Influence table:

IC11	Insert	Delete	Update
GIAOVIEN	+	-	+ (MABM)
BOMON	-	+	+(MABM)

Example 12

- Department head must be a lecturer
  - Context: BOMON, GIAOVIEN
  - Content:

$$(\forall t)(BOMON(t) \wedge (\exists s)(GIAOVIEN(s) \wedge s.MAGV = t.TRUONGBM))$$

  - Influence table:

IC_{12}	Insert	Delete	Update
GIAOVIEN	-	+	+ (MAGV)
BOMON	+	-	+(TRUONGBM)

IC - Reference (cont.)

- Also called existence dependency
- The context is two relations, but there are cases where it degenerates into a relation
  - Example (IC_2)
    - The line manager of a lecturer must be a lecturer in the same department
    - Context: GIAOVIEN
    - Content:

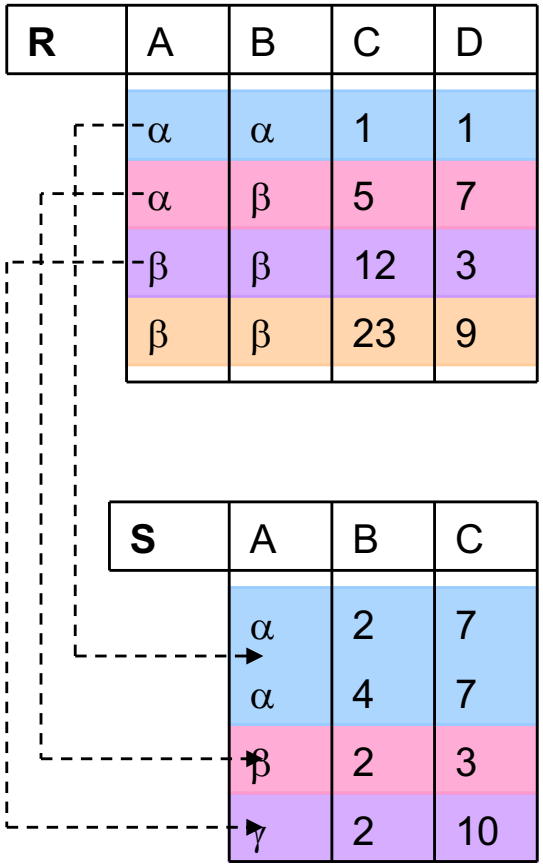
$$(\forall t)(GIAOVIEN(t) \wedge (t.GVQLCM \neq null \Rightarrow (\exists s)(GIAOVIEN(s) \wedge s.MABM = t.MABM \wedge s.MAGV = t.GVQLCM)))$$

    - Influence table

IC_2	Insert	Delete	Update
GIAOVIEN	+	+	+ (GVQLCM, MABM)

IC – Multiple tuples through multiple relations

- IC is defined between tuples in multiple relations



Example 13

- Each project must have at least one work
  - Context: DETAI, CONGVIEC
  - Content:

$$(\forall t)\ (DETAI(t) \wedge (\exists s)(CONGIVEC(s) \wedge t.MADT = s.MADT))$$

  - Influence table:

IC13	Insert	Delete	Update
DETAI	+	-	+(MADT)
CONGVIEC	-	+	+ (MADT)

Example 14

- Each department must have at least one lecturer
  - Context: GIAOVIEN, BOMON
  - Content:

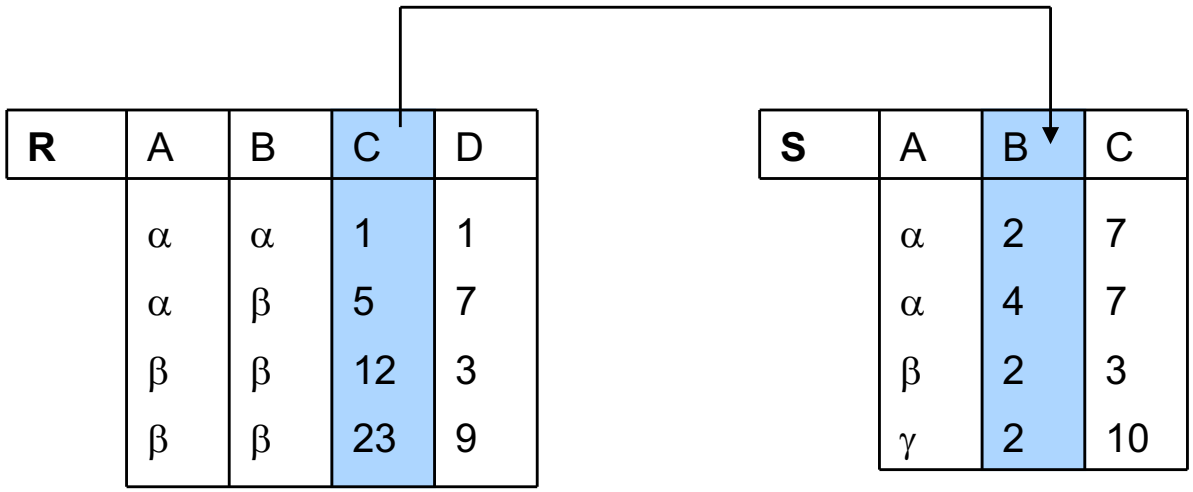
    $(\forall t)\ (BOMON(t) \wedge (\exists s)(GIAOVIEN(s) \wedge t.MABM = s.MABM))$

  - Influence table:

IC14	Insert	Delete	Update
BOMON	+	-	+(MABM)
GIAOVIEN	-	+	+ (MABM)

IC – Multiple attributes through multiple relation

- IC is defined between attributes across multiple relations



R	A	B	C	D
	α	α	1	1
	α	β	5	7
	β	β	12	3
	β	β	23	9

S	A	B	C
	α	2	7
	α	4	7
	β	2	3
	γ	2	10

Example 15

- The birthday of the department head must be less than the date of acceptance of the head position

  - Context: GIAOVIEN, BOMON
  - Content:

$$(\forall t)(BOMON(t) \wedge (\forall s)(GIAOVIEN(s) \wedge (s.MAGV = t.TRUONGBM \Rightarrow s.NGAYSINH < t.NGAYNHANCHUC)))$$

  - Influence table:

IC_{15}	Insert	Delete	Update
GIAOVIEN	-	–	+ (NGAYSINH)
BOMON	+	–	+ (NGAYNHANCHUC, TRUONGBM)

Example 16

- Allowance of a work must be smaller than the budget of the project.
  - Bối cảnh: THAMGIADT, DETAI
  - Biểu diễn:

$$(\forall t)(THAMGIADT(t) \wedge (\forall s)(DETAI(s) \wedge (s.MADT = t.MADT \Rightarrow t.PHUCAP < s.KINHPHI)))$$

  - Bảng tầm ảnh hưởng:

R16	Thêm	Xóa	Sửa
THAMGIADT	+	–	+ (PHUCAP)
DETAI	-	–	+ (KINHPHI)

IC - Inference/calculated attribute

- Calculated attribute (also called inference attribute)
  - Its value is calculated from other attributes
- When a database has a calculated attribute
  - IC ensures the link between the calculated attributes with the source attributes is consistently maintainted

Example 17

- **BOMON**(MABM, TENBM, TRUONGBM, NGAYNHANCHUC, SO_GV)
- The attribute SO_GV must be equal with the number of lecturers of the department
  - Context: GIAOVIEN, BOMON
  - Content:

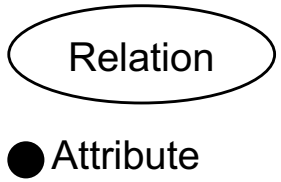
$$(\forall t)(BOMON(t) \wedge t.SO\_GV = \textbf{card}(\{ s \mid GIAOVIEN(s) \wedge s.MABM = t.MABM\}))$$

  - Influence table:

IC_{17}	Insert	Delete	Update
GIAOVIEN	+	+	+ (MABM)
BOMON	–	–	+ (SO_GV)

IC – Relations form a cycle in relation graph

- Database schema can be presented by a graph
  - Vertex (đỉnh)
    - Relation
    - Attribute

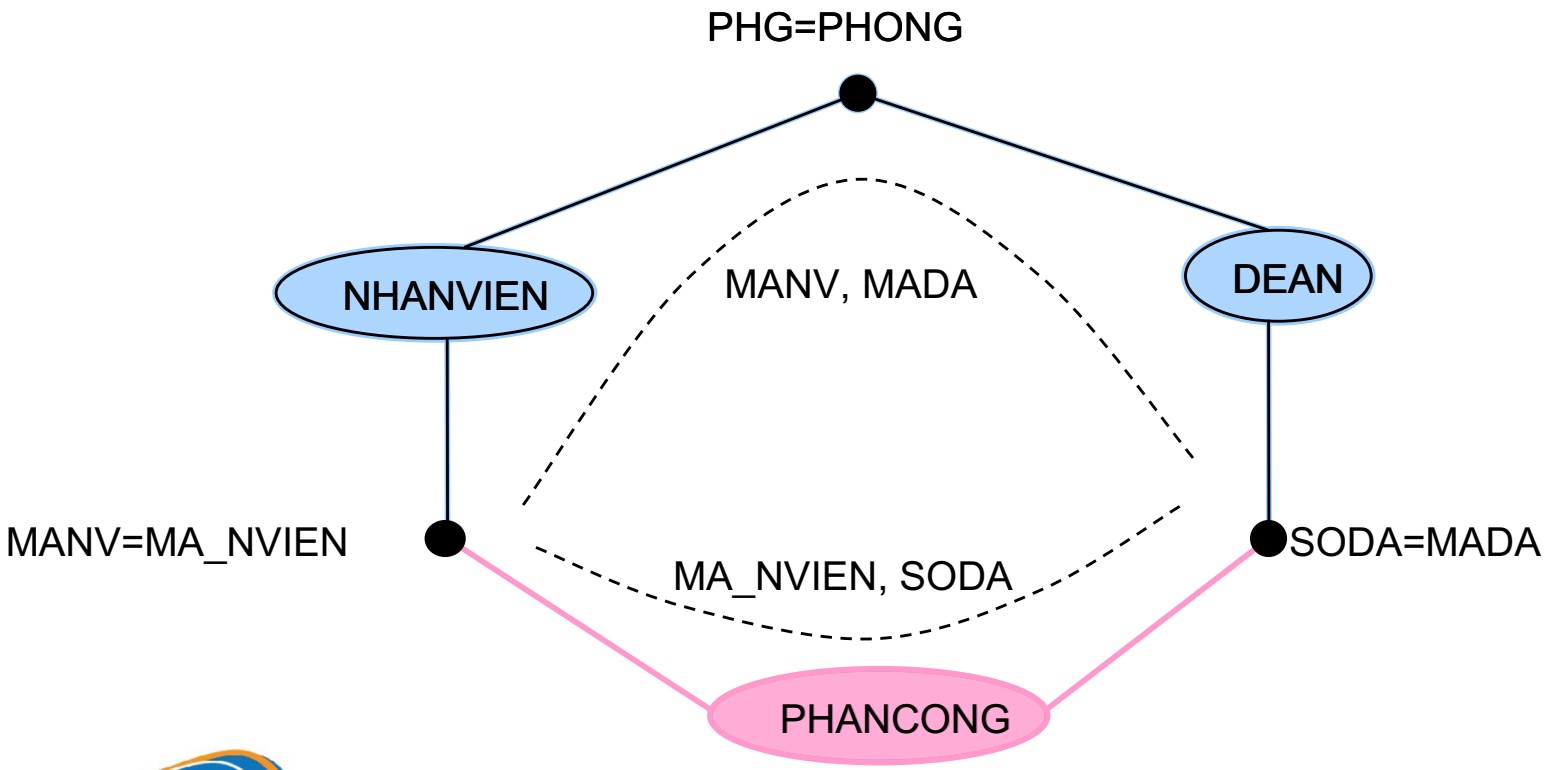


  - Edge
    - A line connecting a relation vertex to an attribute vertex in the database schema

- Cycle
  - Graph appears closed path ~ Acyclic database schema

Example 17

- Employees are only assigned to projects in charged by their departments



Example 17 (cont.)

- Context: NHANVIEN, DEAN, PHANCONG
- Content:

$$NVDA \leftarrow NHANVIEN \bowtie_{PHG=PHONG} DEAN$$

$$(\forall t)\,(PHANCONG(t) \wedge (\exists s)(NVDA(s) \wedge t.MA\_NVIEN = s.MANV \wedge t.MADA = s.SODA\ ))$$

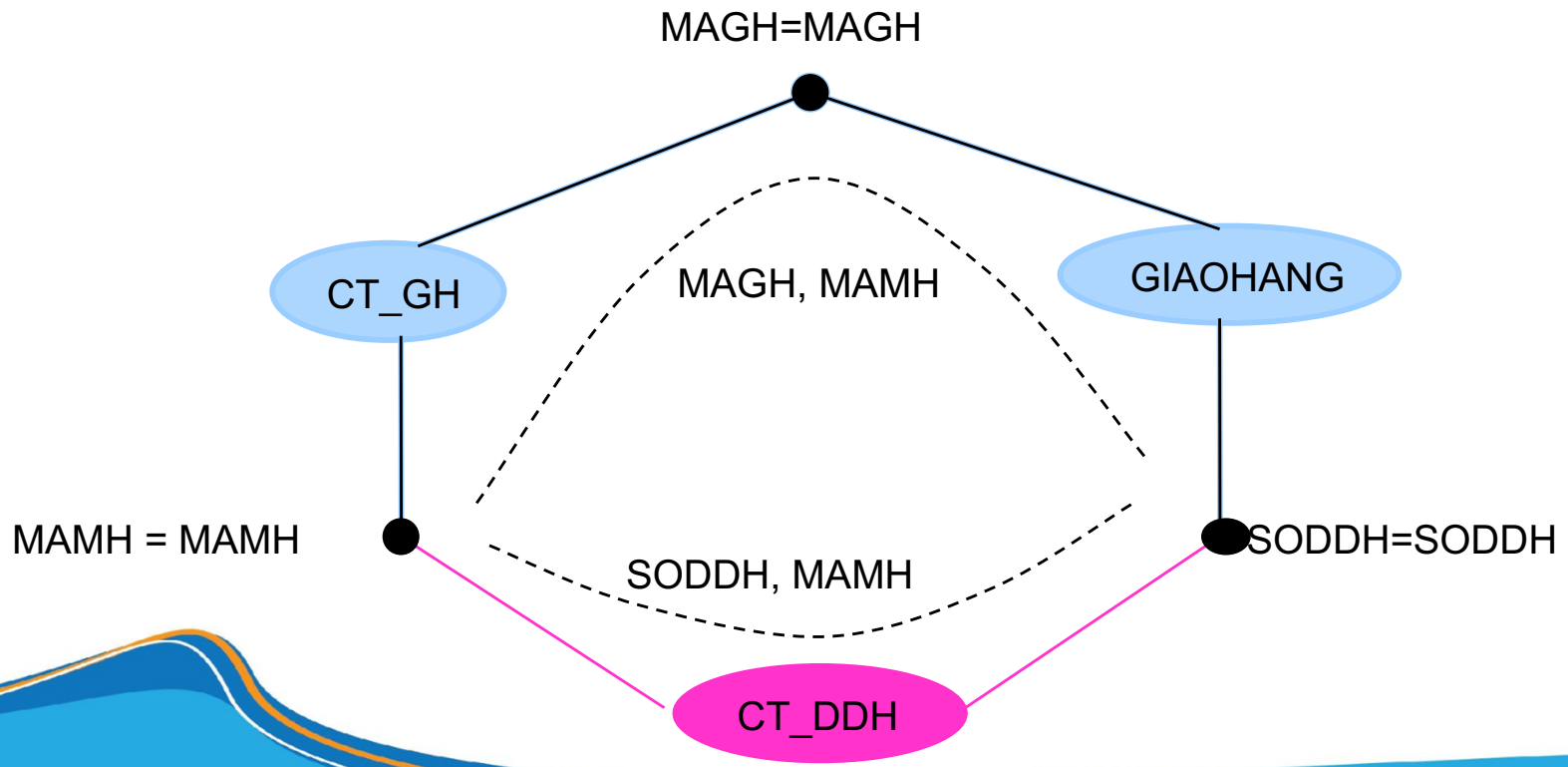
- Influence table:

IC_{17}	Insert	Delete	Update
NHANVIEN	–	–	+ (MANV,PHG)
DEAN	–	–	+ (MADA,PHONG)
PHANCONG	+	–	+ (MA_NVIEN,SODA)

Example 18

- DDH (SODDH, NGAYDH, MAKH)
- CT_DDH (SODDH, MAMH, SOLUONG, DONGIA)
- GIAOHANG(MAGH, NGAYGH, TONGTIEN, SODDH)
- CT_GH (MAGH, MAMH)

IC: Only products ordered by customer are allowed to be delivered.



Content

- Overview
- Characteristics of Integrity Constraints
- Classification
- **Implementation**
  - Assertion
  - Trigger
  - Transaction (giao tác)
  - Stored Procedure (thủ tục lưu trữ nội)
  - Application (ứng dụng)

Implementation

- The ICs are implemented by:
  - Primary key
  - Foreign key
  - Check constraint
  - Assertion
  - Trigger
  - Transaction

Assertion

- Is an SQL expression that always returns the value TRUE at all times.
  - Users need to tell what must be true

- Syntax

CREATE ASSERTION <Tên_assertion> **CHECK** (<Điều_kiện>)

DROP ASSERTION <Tên_assertion>

Example 15

- Ngày sinh của trưởng bộ môn phải nhỏ hơn ngày nhận chức

```
CREATE ASSERTION R12 CHECK (
        NOT EXISTS (
                SELECT *
                FROM GIAOVIEN, BOMON
                WHERE MAGV=TRUONGBM
                AND NGAYSINH > NGAYNHANCHUC )
)
```

Example 19

- Lương của trưởng bộ môn phải lớn hơn 50000

```
CREATE ASSERTION R15 CHECK (
        NOT EXISTS (
                SELECT *
                FROM GIAOVIEN, BOMON
                WHERE MAGV=TRUONGBM
                AND LUONG < 50000 )
)
```

Example 19 (cont.)

- Lương của trưởng bộ môn phải lớn hơn 50000

Check Constraint

```
ALTER TABLE BOMON (
        TENBM NVARCHAR(50) UNIQUE,
        MABM CHAR(10) NOT NULL,
        TRUONGBM CHAR(10),
        NGAYNHANCHUC DATETIME,
        CONSTRAINT CHK_BM_LUONGTRUONGBM CHECK (
                TRUONGBM NOT IN (SELECT MAGV FROM
GIAOVIEN
                                WHERE LUONG <= 50000 ))
)
```

Example 16

- Số lượng giáo viên của mỗi bộ môn không quá 20 người

```
CREATE ASSERTION R16 CHECK (
        20 >= ALL ( SELECT COUNT(MAGV)
                FROM GIAOVIEN
                GROUP BY MABM )
)
```

Example 16 (cont.)

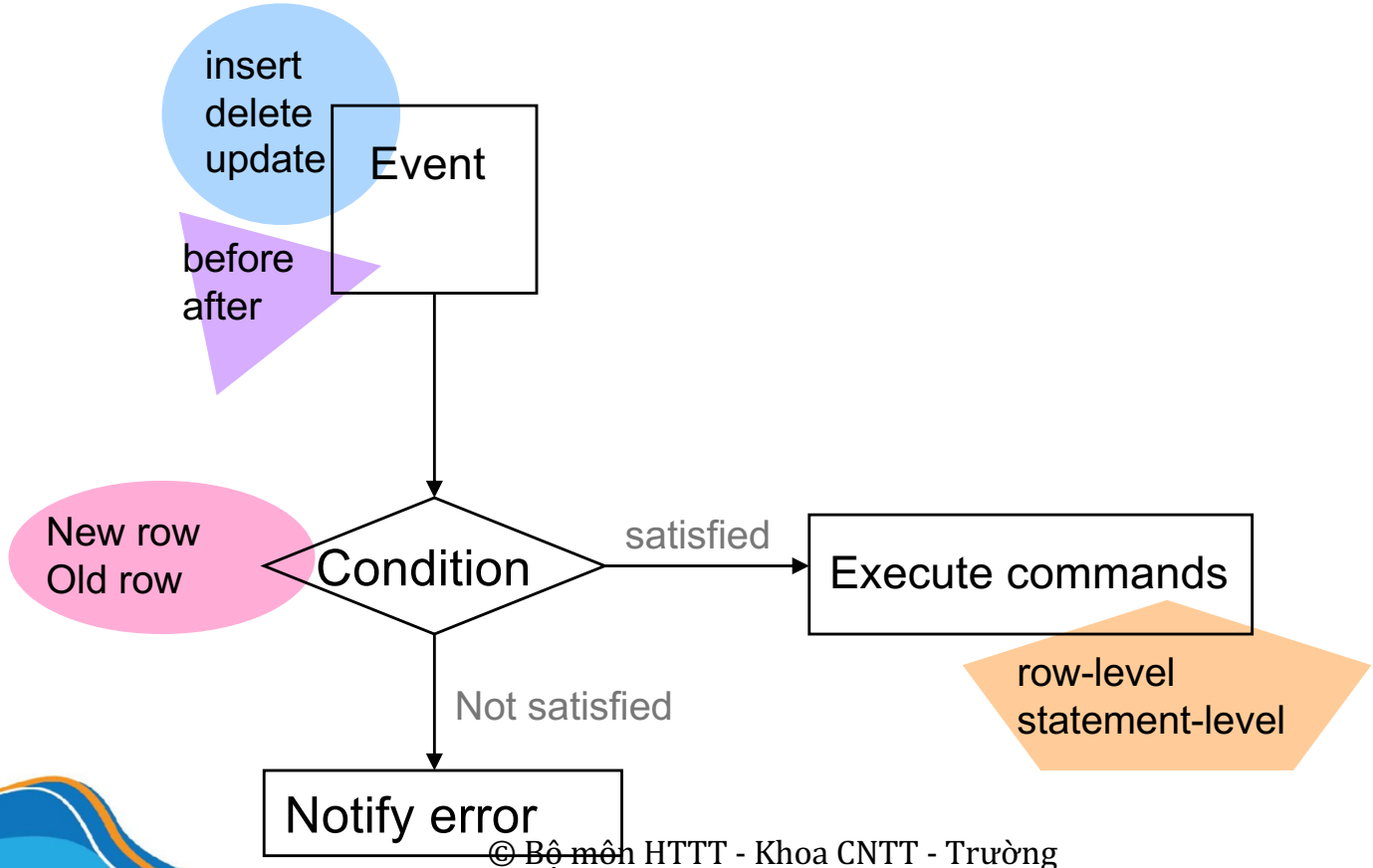
- Số lượng giáo viên của mỗi bộ môn không quá 20 người

Check Constraint

```
ALTER TABLE GIAOVIEN ADD
CONSTRAINT CHK_GV_SLGVBM CHECK (
        20 >= ALL ( SELECT COUNT(MAGV) FROM GIAOVIEN
                    GROUP BY MABM ))
```

Trigger

- A set of commands that are automatically executed when an event occurs in the database



Trigger (cont.)

- Syntax

```
CREATE TRIGGER <Trigger_name>
AFTER|BEFORE   INSERT|UPDATE|DELETE   ON   <Table>
REFERENCING
        NEW   ROW|TABLE   AS   <Name_1>
        OLD   ROW|TABLE   AS   <Name_2>
FOR EACH ROW | FOR EACH STATEMENT
WHEN (<Condition>)
        <Tập_lệnh_SQL>
```

```
DROP TRIGGER <Trigger_name>
```

Example 15

- The salary of the department head must be greater than 50000

```
CREATE TRIGGER TR_BM_UPD
AFTER UPDATE OF TRUONGBM ON BOMON
REFERENCING
        NEW ROW AS NewTuple
FOR EACH ROW
WHEN (50000 >= (SELECT LUONG        FROM GIAOVIEN
                        WHERE MAGV=NewTuple.TRUONGBM))
        Notify error to users
```

Example 15 (cont.)

- The salary of the department head must be greater than 50000

```
CREATE TRIGGER TR_BM_UPD
AFTER UPDATE OF TRUONGBM ON BOMON
REFERENCING
        NEW ROW AS NewTuple
        OLD ROW AS OldTuple
FOR EACH ROW
WHEN (50000 >= (SELECT LUONG        FROM GIAOVIEN
                        WHERE MAGV=NewTuple.TRUONGBM))
        UPDATE BOMON
        SET TRUONGBM=OldTuple.TRUONGBM
        WHERE TRUONGBM=NewTuple.TRUONGBM
```

Example 15 (cont.)

- The salary of the department head must be greater than 50000

```
CREATE TRIGGER TR_BM_UPD
AFTER UPDATE OF LUONG ON GIAOVIEN
REFERENCING
        NEW ROW AS NewTuple
        OLD ROW AS OldTuple
FOR EACH ROW
WHEN (NewTuple.LUONG <= 50000 AND NewTuple.MAGV IN (
                SELECT TRUONGBM FROM BOMON ))
        UPDATE GIAOVIEN
        SET LUONG=OldTuple.LUONG
        WHERE LUONG=NewTuple.LUONG
```

Transaction

- A set of instructions that perform a task/transaction in a database, such that
  - Or all instructions are executed successfully
  - Or no instruction is executed

- Ex: transfer money in a bank

```
Begin transaction  Chuyển_tiền
        Giảm tiền trong tài khoản người gửi
        Tăng tiền trong tài khoản người nhận
        Nếu tất cả đều thành công thì complete
        Ngược lại roll back
End transaction
```

Transaction (cont.)

- A transaction ensure
  - Atomicity (Tính nguyên tố)
  - Consistency (Tính nhất quán của CSDL)
    - Related ICs are not violated
      - While executing the transaction
      - Before and after executing the transaction

Example

- Each match is a competition of exactly 2 teams

```
Giao tác Thêm_trận_đấu(t, s)
        Thêm t vào THIDAU
        Thêm s vào THIDAU
        Nếu có một thao tác thất bại thì
                Quay lui giao tác
        Ngược lại
                Hoàn tất giao tác
        Cuối nếu
Cuối giao tác
```

Example

Giao tác Xóa_trận_đấu(ngay, gio)
    Với mọi s∈THIDAU (s.NGAY=ngay ∧ s.GIO=gio)
        Xóa s khỏi THIDAU
    Cuối với mọi
    Nếu có một thao tác thất bại thì
        Quay lui giao tác
    Ngược lại
        Hoàn tất giao tác
    Cuối nếu
Cuối giao tác

Example

- Each invoice must have at least one invoice detailed line

```
Giao tác Thêm_hóa_đơn
        Thêm HOADON
        Thêm chi tiết thứ 1 vào CTHD
        Thêm chi tiết thứ 2 vào CTHD
        …
        Nếu có một thao tác thêm thất bại thì
                Quay lui giao tác
        Ngược lại
                Hoàn tất giao tác
        Cuối nếu
Cuối giao tác
```

Example

```
Giao tác Thêm_hóa_đơn
        Thêm HOADON
        Thêm chi tiết thứ 1 vào CTHD
        Thêm chi tiết thứ 2 vào CTHD
        …
        Nếu có một thao tác thêm thất bại thì
                Quay lui giao tác
        Ngược lại
                Hoàn tất giao tác
        Cuối nếu
Cuối giao tác
```

Stored Procedure

- DBMSs provide a way to store functions or procedures
  - Stored in the database schema
  - Used in SQL statements

- Syntax

```
CREATE PROCEDURE <Tên_thủ_tục> <DS_tham_số>
AS
        Khai báo biến cục bộ
        Thân chương trình
GO
EXEC <Tên_thủ_tục> <DS_ tham_số>
```

Example

- Each match is a competition of exactly 2 teams

```
CREATE PROCEDURE Thêm_trận_đấu
t THIDAU , s THIDAU
AS
        begin tran
                Thêm t vào THIDAU
                If @@error<>0 rollback tran

                Thêm s vào THIDAU
                If @@error<>0    rollback tran
        commit tran
GO

EXEC Thêm_trận_đấu  x, y
```

Notice

- DBMS will check ICs
  - After an update operation has taken place on the database
  - At the end of each transaction
- Where should an IC be implemented?
  - DBMS
  - Application

  - Too much Trigger → slow system
  - Stored Procedure → high performance