



Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

Database Management Systems

Module 28: Relational Database Design/8: Case Study

Partha Pratim Das

Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

ppd@cse.iitkgp.ac.in



Module 28

Partha Pratim
Das

Objectives & Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- Learnt how to decompose a schema into 3NF while preserving dependency and lossless join
- Learnt how to decompose a schema into BCNF with lossless join



Module 28

Partha Pratim
Das

Objectives & Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- To design the schema for a Library Information System



Module 28

Partha Pratim
Das

Objectives & Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- Library Information System



Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

We are given to design a relational database schema for a Library Information System (LIS) of an Institute

- The specification document of the LIS has already been shared with you
- In this presentation, we include the key points from the Specs; but the actual document must be referred to
- We carry out the following tasks in the module:
 - Identify the Entity Sets with attributes
 - Identify the Relationships
 - Build the initial set of relational schema
 - Refine the set of schema with FDs that hold on them
 - Finalize the design of the schema
- The coding of various queries in SQL, based on these schema are left as exercises



LIS Specs Excerpts

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- An institute library has 200000+ books and 10000+ members
- Books are regularly issued by members on loan and returned after a period.
- The library needs an LIS to manage the books, the members and the issue-return process
- Every **book** has
 - title
 - author (in case of multiple authors, only the first author is maintained)
 - publisher
 - year of publication
 - ISBN number (which is unique for the publication), and
 - accession number (which is the unique number of the copy of the book in the library)
 - *There may be multiple copies of the same book in the library*



LIS Specs Excerpts (2)

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- There are four categories of **members** of the library:
 - undergraduate students
 - post graduate students
 - research scholars, and
 - faculty members
- Every **student** has
 - ▷ name
 - ▷ roll number
 - ▷ department
 - ▷ gender
 - ▷ mobile number
 - ▷ date of birth, and
 - ▷ degree
 - undergrad
 - grad
 - doctoral



LIS Specs Excerpts (3)

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- Every **faculty** has
 - name
 - employee id
 - department
 - gender
 - mobile number, and
 - date of joining
- Library also issues a unique **membership number to every member**. Every member has a **maximum quota** for the number of books she / he can issue for the maximum duration allowed to her / him. Currently these are set as:
 - Each undergraduate student can issue up to 2 books for 1 month duration
 - Each postgraduate student can issue up to 4 books for 1 month duration
 - Each research scholar can issue up to 6 books for 3 months duration
 - Each faculty member can issue up to 10 books for six months duration



LIS Specs Excerpts (4)

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- The library has the following **rules** for issue:
 - A book may be issued to a member if it is not already issued to someone else (trivial)
 - A book may not be issued to a member if another copy of the same book is already issued to the same member
 - No issue will be done to a member if at the time of issue one or more of the books issued by the member has already exceeded its duration of issue
 - No issue will be allowed also if the quota is exceeded for the member
 - It is assumed that the name of every author or member has two parts
 - ▷ first name
 - ▷ last name



Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

LIS should support the following operations / query:

- Add / Remove members, categories of members, books.
- Add / Remove / Edit quota for a category of member, duration for a category of member.
- Check if the library has a book given its title (part of title should match). If yes: title, author, publisher, year and ISBN should be listed.
- Check if the library has a book given its author. If yes: title, author, publisher, year and ISBN should be listed.
- Check if a copy of a book (given its ISBN) is available with the library for issue. All accession numbers should be listed with issued or available information.
- Check the available (free) quota of a member.
- Issue a book to a member. This should check for the rules of the library.
- Return a book from a member.
- and so on



Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- *Every book has title, author (in case of multiple authors, only the first author is maintained), publisher, year of publication, ISBN number (which is unique for the publication), and accession number (which is the unique number of the copy of the book in the library). There may be multiple copies of the same book in the library*
- Entity Set:
 - **books**
- Attributes:
 - title
 - author_name (composite)
 - publisher
 - year
 - ISBN_no
 - accession_no



Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- *Every student has name, roll number, department, gender, mobile number, date of birth, and degree (undergrad, grad, doctoral)*
- Entity Set:
 - **students**
- Attributes:
 - member_no – is unique
 - name (composite)
 - roll_no – is unique
 - department
 - gender
 - mobile_no – may be null
 - dob
 - degree



Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- *Every faculty has name, employee id, department, gender, mobile number, and date of joining*
- Entity Set:
 - **faculty**
- Attributes:
 - member_no – is unique
 - name (composite)
 - id – is unique
 - department
 - gender
 - mobile_no – may be null
 - doj



Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- *Library also issues a unique membership number to every member. There are four categories of members of the library: undergraduate students, post graduate students, research scholars, and faculty members*
- Entity Set:
 - **members**
- Attributes:
 - member_no
 - member_type (takes a value in ug, pg, rs or fc)



Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- *Every member has a maximum quota for the number of books she / he can issue for the maximum duration allowed to her / him. Currently these are set as:*
 - *Each undergraduate student can issue up to 2 books for 1 month duration*
 - *Each postgraduate student can issue up to 4 books for 1 month duration*
 - *Each research scholar can issue up to 6 books for 3 months duration*
 - *Each faculty member can issue up to 10 books for six months duration*
- Entity Set:
 - **quota**
- Attributes:
 - member_type
 - max_books
 - max_duration



Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- *Though not explicitly stated, library would have staffs to manage the LIS*
- Entity Set:
 - **staff**
- Attributes: (speculated – to ratify from customer)
 - name (composite)
 - id – is unique
 - gender
 - mobile_no
 - doj



Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- *Books are regularly issued by members on loan and returned after a period. The library needs an LIS to manage the books, the members and the issue-return process*
- Relationship
 - **book_issue**
- Involved Entity Sets
 - **students / faculty / members**
 - ▷ member_no
 - **books**
 - ▷ accession_no
- Relationship Attribute
 - doi – date of issue
- Type of relationship
 - Many-to-one from **books**



Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- **books**(title, author_fname, author_lname, publisher, year, ISBN_no, accession_no)
- **book_issue**(members, accession_no, doi)
- **members**(member_no, member_type)
- **quota**(member_type, max_books, max_duration)
- **students**(member_no, student_fname, student_lname, roll_no, department, gender, mobile_no, dob, degree)
- **faculty**(member_no, faculty_fname, faculty_lname, id, department, gender, mobile_no, doj)
- **staff**(staff_fname, staff_lname, id, gender, mobile_no, doj)



Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- **books**(title, author_fname, author_lname, publisher, year, ISBN_no, accession_no)
 - ISBN_no \rightarrow title, author_fname, author_lname, publisher, year
 - accession_no \rightarrow ISBN_no
 - Key: accession_no
- Redundancy of book information across copies
- Good to normalize:
 - **book_catalogue**(title, author_fname, author_lname, publisher, year, ISBN_no)
 - ▷ ISBN_no \rightarrow title, author_fname, author_lname, publisher, year
 - ▷ Key: ISBN_no
 - **book_copies**(ISBN_no, accession_no)
 - ▷ accession_no \rightarrow ISBN_no
 - ▷ Key: accession_no
- Both in BCNF. Decomposition is lossless join and dependency preserving



LIS Schema Refinement (2): book_issue

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- **book_issue**(member_no, accession_no, doi)
 - member_no, accession_no → doi
 - Key: members, accession_no
- In BCNF



LIS Schema Refinement (3): quota

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- **quota**(member_type, max_books, max_duration)
 - member_type \rightarrow max_books, max_duration
 - Key: member_type
- In BCNF



LIS Schema Refinement (4): members

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- **members**(member_no, member_type)
 - member_no \rightarrow member_type
 - Key: member_no
 - Value constraint on member_type
 - ▷ ug, pg, or rs: if the member is a student
 - ▷ fc: if the member is a faculty
 - In BCNF
 - How to determine the member_type?

LIS Schema Refinement (5): students

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- **students**(member_no, student_fname, student_lname, roll_no, department, gender, mobile_no, dob, degree)
 - $\text{roll_no} \rightarrow \text{student_fname}, \text{student_lname}, \text{department}, \text{gender}, \text{mobile_no}, \text{dob}, \text{degree}$
 - $\text{member_no} \rightarrow \text{roll_no}$
 - $\text{roll_no} \rightarrow \text{member_no}$
 - 2 Keys: $\text{roll_no} \mid \text{member_no}$
- In BCNF
- Issues:
 - member_no is needed for issue / return queries. It is unnecessary to have student's details with that.
 - member_no may also come from faculty relation.
 - member_type is needed for issue / return queries. This is implicit in degree – not explicitly given.



LIS Schema Refinement (6): faculty

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- **faculty**(member_no, faculty_fname, faculty_lname, id, department, gender, mobile_no, doj)
 - $\text{id} \rightarrow \text{faculty_fname}, \text{faculty_lname}, \text{department}, \text{gender}, \text{mobile_no}, \text{doj}$
 - $\text{id} \rightarrow \text{member_no}$
 - $\text{member_no} \rightarrow \text{id}$
 - 2 Keys: $\text{id} \mid \text{member_no}$
- In BCNF
- Issues:
 - member_no is needed for issue / return queries. It is unnecessary to have faculty details with that.
 - member_no may also come from **students** relation.
 - member_type is needed for issue / return queries. This is implicit by the fact that we are in faculty relation.



LIS Schema Refinement (7): Query

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- Consider a query:
 - Get the name of the member who has issued the book having accession number = 162715
 - ▷ If the member is a student,
 - SELECT student_fname as First_Name, student_lname as Last_Name
 - FROM **students**, **book_issue**
 - WHERE accession_no = 162715 AND book_issue.member_no = students.member_no;
 - ▷ If the member is a faculty,
 - SELECT faculty_fname as First_Name, faculty_lname as Last_Name
 - FROM **faculty**, **book_issue**
 - WHERE accession_no = 162715 AND book_issue.member_no = faculty.member_no;
 - **Which query to fire!**



LIS Schema Refinement (8): members

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

There are 4 categories of members: ug students, grad students, research scholars, and faculty members. This leads to the following specialization relationships:

- Consider the entity set **members** of a library and refine:
 - Attributes:
 - ▷ member_no
 - ▷ member_class – ‘student’ or ‘faculty’, used to choose table
 - ▷ member_type – ug,pg, rs, fc, ...
 - ▷ roll_no (if member_class – ‘student’. Else null)
 - ▷ id (if member_class – ‘faculty’. Else null)
- We can then exploit some hidden relationship:
 - students IS_A members
 - faculty IS_A members
- Type of relationship
 - One-to-one



LIS Schema Refinement (9): Query

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- Consider the access query again:
 - Get the name of the member who has issued the book having accession number = 162715

```
SELECT
((SELECT faculty_fname as First_Name, faculty_lname as Last_Name
FROM faculty
WHERE member_class = 'faculty' AND members.id = faculty.id)
UNION
(SELECT student_fname as First_Name, student_lname as Last_Name
FROM students
WHERE member_class = 'student' AND members.roll_no = students.roll_no))
FROM members, book_issue
WHERE accession_no = 162715 AND book_issue.member_no = members.member_no;
```



LIS Schema Refinement (10): members

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- **members**(member_no, member_class, member_type, roll_no, id)
 - member_no → member_type, member_class, roll_no, id
 - member_type → member_class
 - Key: member_no



LIS Schema Refinement (11): students

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- **students**(student_fname, student_lname, roll_no, department, gender, mobile_no, dob, degree)
 - roll_no → student_fname, student_lname, department, gender, mobile_no, dob, degree
 - Keys: roll_no
 - *Note:*
 - ▷ member_no is no longer used
 - ▷ member_type and member_class are set in **members** from degree at the time of creation of a new record.



LIS Schema Refinement (12): faculty

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- **faculty**(faculty_fname, faculty_lname, id, department, gender, mobile_no, doj)
 - id \rightarrow faculty_fname, faculty_lname, department, gender, mobile_no, doj
 - Keys: id
 - *Note:*
 - ▷ member_no is no longer used
 - ▷ member_type and member_class are set in **members** at the time of creation of a new record



LIS Schema Refinement (13): Final

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- **book_catalogue**(title, author_fname, author_lname, publisher, year, ISBN_no)
- **book_copies**(ISBN_no, accession_no)
- **book_issue**(member_no, accession_no, doi)
- **quota**(member_type, max_books, max_duration)
- **members**(member_no, member_class, member_type, roll_no, id)
- **students**(student_fname, student_lname, roll_no, department, gender, mobile_no, dob, degree)
- **faculty**(faculty_fname, faculty_lname, id, department, gender, mobile_no, doj)
- **staff**(staff_fname, staff_lname, id, gender, mobile_no, doj)



Module Summary

Module 28

Partha Pratim
Das

Objectives &
Outline

Library
Information
System

Specification

Entity Sets

Relationships

Relational Schema

Schema Refinement

Final Schema

Module Summary

- Using the specification for a Library Information System, we have illustrated how a schema can be designed and then refined for finalization
- Coding of various queries based on these schema are left as exercises

Slides used in this presentation are borrowed from <http://db-book.com/> with kind permission of the authors.

Edited and new slides are marked with “PPD”.