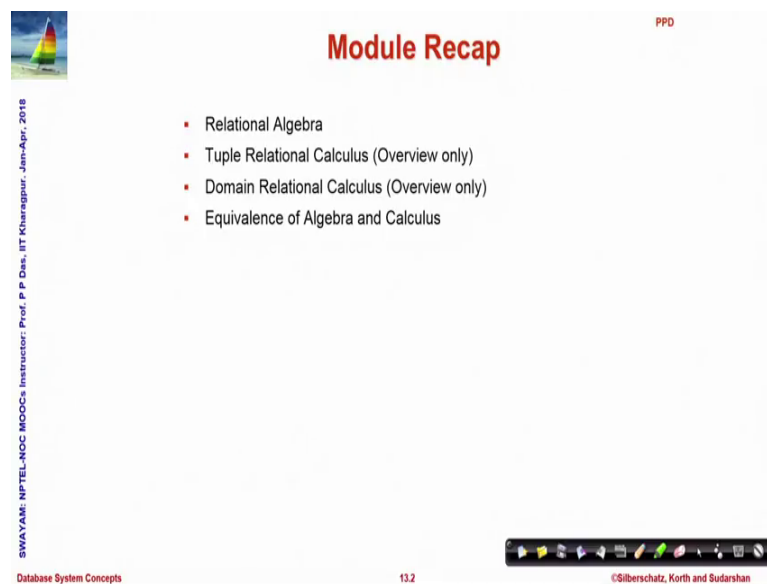


Database Management System
Prof. Partha Pratim Das
Department of Computer Science & Engineering
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Lecture – 13
Entity-Relationship Model/1

Welcome to module 13 of Database Management Systems. In this module and the next 2 we will discuss about Entity Relationship Model.

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The slide is titled "Module Recap" in red text. It features a small image of a sailboat in the top left corner. The main content is a bulleted list of topics covered in the module. The slide also includes a vertical text on the left side, a footer with the course name and slide number, and a copyright notice at the bottom right.

PPD

- Relational Algebra
- Tuple Relational Calculus (Overview only)
- Domain Relational Calculus (Overview only)
- Equivalence of Algebra and Calculus

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So, far we have had a good look into the SQL language, the query language and it is formal basis in terms of relational algebra and calculi.

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PPD

Module Objectives

- To understand the Design Process for Database Systems
- To study the E-R Model for real world representation

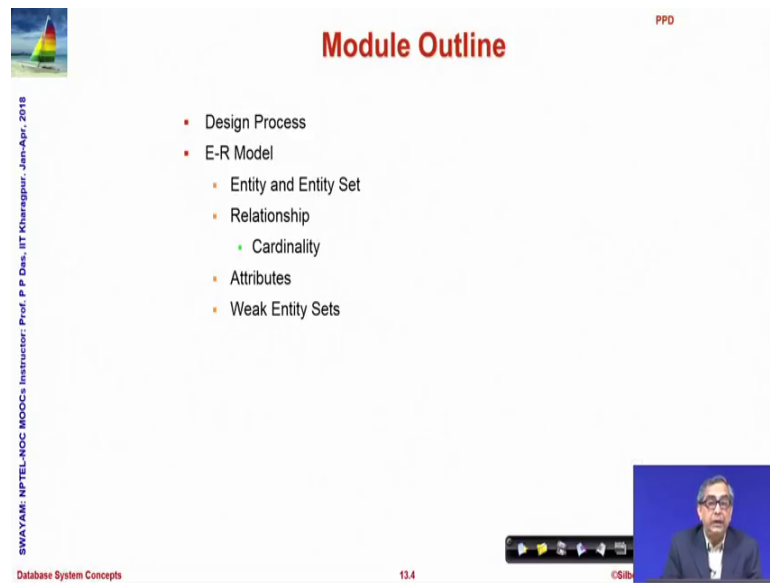
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In this module we will un try to understand the design process for database systems, because so far whatever we have done we have assumed that the schema is known to us, that some instance is given to us and then we have tried to extract different query information from the relation; but now we will look into how do we model the real world and actually get into the design process.

So, after an overview of the design process we would study entity relationship model, which is used to represent the real world whatever exists in the real world that will have to be represented for our use and final representation in terms of different relations.

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PPD

Module Outline

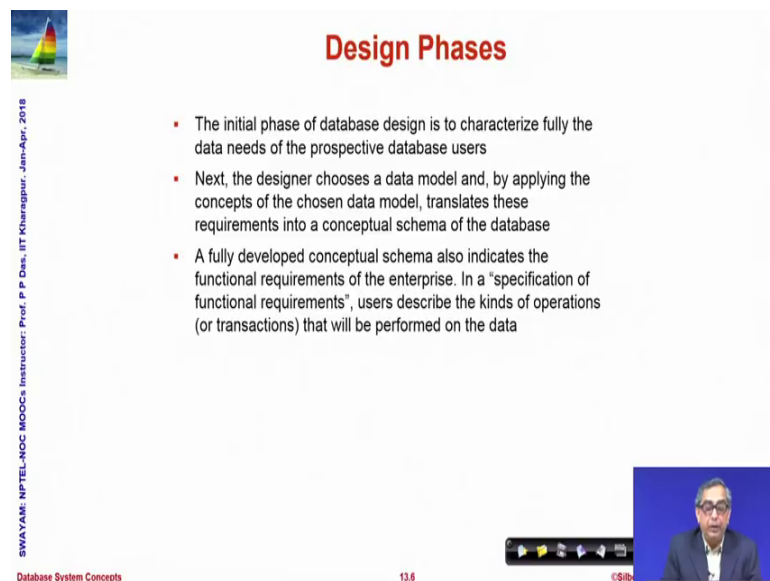
- Design Process
- E-R Model
 - Entity and Entity Set
 - Relationship
 - Cardinality
 - Attributes
 - Weak Entity Sets

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The design process at an abstract level.

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Design Phases

- The initial phase of database design is to characterize fully the data needs of the prospective database users
- Next, the designer chooses a data model and, by applying the concepts of the chosen data model, translates these requirements into a conceptual schema of the database
- A fully developed conceptual schema also indicates the functional requirements of the enterprise. In a "specification of functional requirements", users describe the kinds of operations (or transactions) that will be performed on the data

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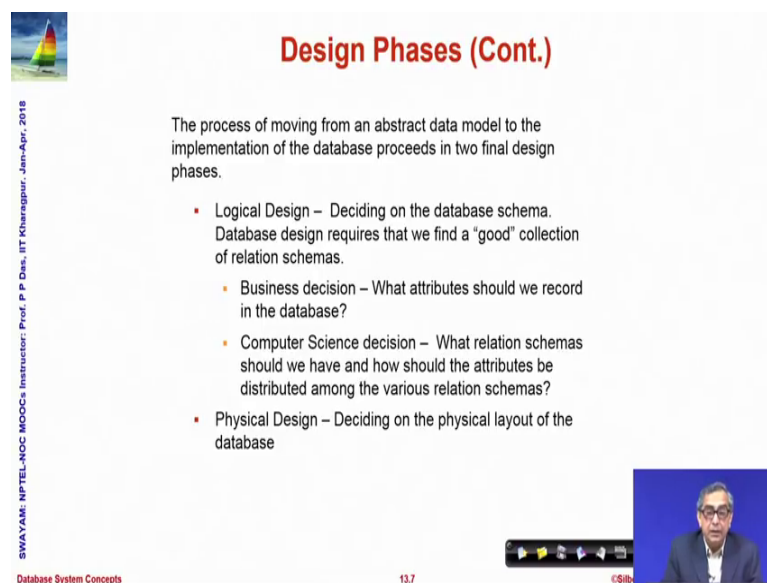
The initial phase of database design certainly has to characterize what data is required to be maintained for an enterprise. So, whether I am doing, if I am doing an university database naturally we will need to identify that what are the data needs the students need to be described, the instructors need to be described, the courses sections time slots grades examinations etc; but if I am trying to deal with an world which is say railway

reservation, then I will need to deal with stations trains date (Refer Time: 02:26) the different classes of coach that the train has and so on.

So, the initial phase is to characterize the data requirement next the designer has to choose a data model because, unless we can we cannot deal with a natural language or English kind of description and work towards getting a particular schema.

So, we will need to use a data model and apply the concepts of the data model that we choose and translate the requirements into what is known as a conceptual schema of the database which is not a not a very concrete 1. But, a conceptual one this is what grossly what I want to do and a fully developed conceptual schema will indicate my functional requirements, in terms of what usually is called a specification of functional requirements system requirements. If it will specify what kind of users will be involved what kinds of operations transactions will be performed and so on.

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Design Phases (Cont.)

The process of moving from an abstract data model to the implementation of the database proceeds in two final design phases.

- Logical Design – Deciding on the database schema. Database design requires that we find a "good" collection of relation schemas.
 - Business decision – What attributes should we record in the database?
 - Computer Science decision – What relation schemas should we have and how should the attributes be distributed among the various relation schemas?
- Physical Design – Deciding on the physical layout of the database

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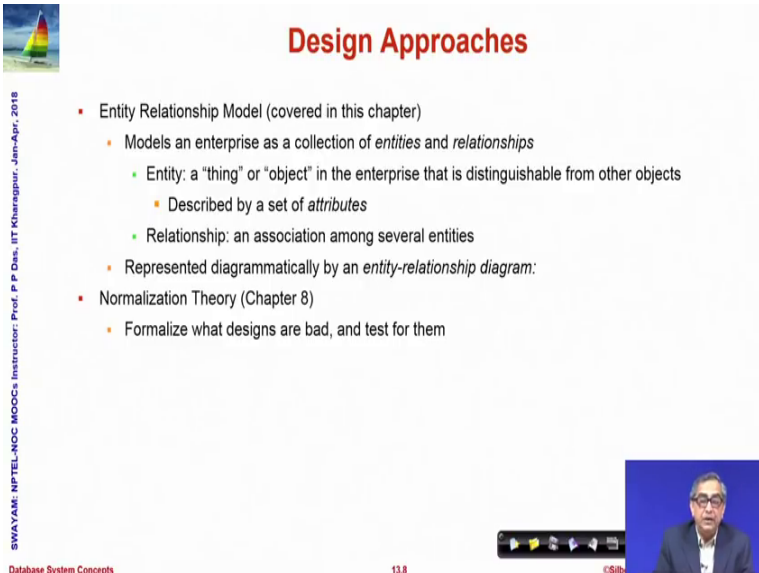
Database System Concepts 13.7 ©Silb

Now, once we have that kind of a conceptual model that abstract that is a conceptual more abstract data model, we will go to the next phase of the design which is finding out what is the more concrete design through a process of logical design. In the process of logical design we will first decide on the database schema, we need to decide on what is a good schema.

So, there are principles to say that what is good and what is not so good, we need to make business decisions to find out which attributes we record in the database; we need to make computer science decision as to how the relational schemas will be interrelated between themselves, how the attributes will be distributed and at a last phase we need to also decide on the physical design which will tell us what is the physical layout of the data.

So, conceptual design refined into logical design finalized with physical design is our gross process of design.

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The slide is titled "Design Approaches" in red text. It features a small image of a sailboat in the top left corner. The main content is a bulleted list:

- Entity Relationship Model (covered in this chapter)
 - Models an enterprise as a collection of *entities* and *relationships*
 - Entity: a "thing" or "object" in the enterprise that is distinguishable from other objects
 - Described by a set of *attributes*
 - Relationship: an association among several entities
 - Represented diagrammatically by an *entity-relationship diagram*:
- Normalization Theory (Chapter 8)
 - Formalize what designs are bad, and test for them

At the bottom of the slide, there is a small video inset of a man speaking, a navigation bar with arrows, and the text "Database System Concepts 13.8 ©Silb". On the left side, there is vertical text: "SWAYAM: NPTEL-NOC MOCs Instructor: Prof. P. Das, IIT Kharagpur, Jan-Apr, 2018".

Now, in this for the conceptual design we primarily follow a model called entity relationship model; that tries to identify the collection of entities and relationships. An entity is nothing, but it is an object is a thing that is distinguishable from other objects. So, if I say that student is an entity then the student is distinguishable from another entity course both of them are distinguishable from a third entity instructor and so on.

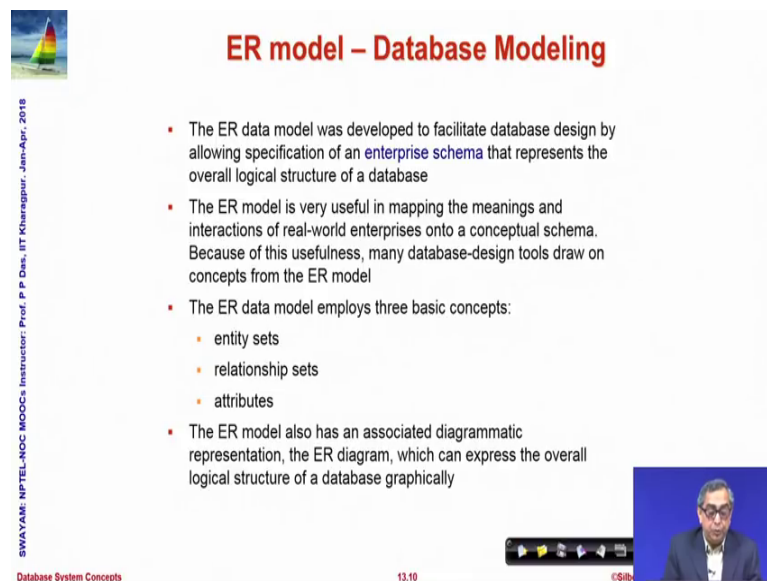
So, every entity for the purpose of distinction is described by a set of attributes or properties and these entities will have relations between them. For example, you can say that a course will be attended by students; students will be advised by instructors. So, this attended by advised by these are relationships or association between several entities and the model which represents initially diagrammatically and then in textual form this kind

of relationship is known as the entity relationship model or the entity relationship diagram.

We will then use it to get a relational set of relational schema which subsequently we normalize; the normalization is nothing but refinement of the design which improves a design to make it better in terms of correctness, in terms of ease of manipulation performance and so on. So, it basically removes bad designs from the database and converts them into good designs; we will talk about this normalization theory later in the course. Right now we are interested only in the entity relationship model, which will be used for conceptual design and then will give us the basis for the logical design in terms of the schemas.

So, let us take a deeper look into the entity relationship model and entity relationship model as I said is developed to facilitate the database design.

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ER model – Database Modeling

- The ER data model was developed to facilitate database design by allowing specification of an enterprise schema that represents the overall logical structure of a database
- The ER model is very useful in mapping the meanings and interactions of real-world enterprises onto a conceptual schema. Because of this usefulness, many database-design tools draw on concepts from the ER model
- The ER data model employs three basic concepts:
 - entity sets
 - relationship sets
 - attributes
- The ER model also has an associated diagrammatic representation, the ER diagram, which can express the overall logical structure of a database graphically

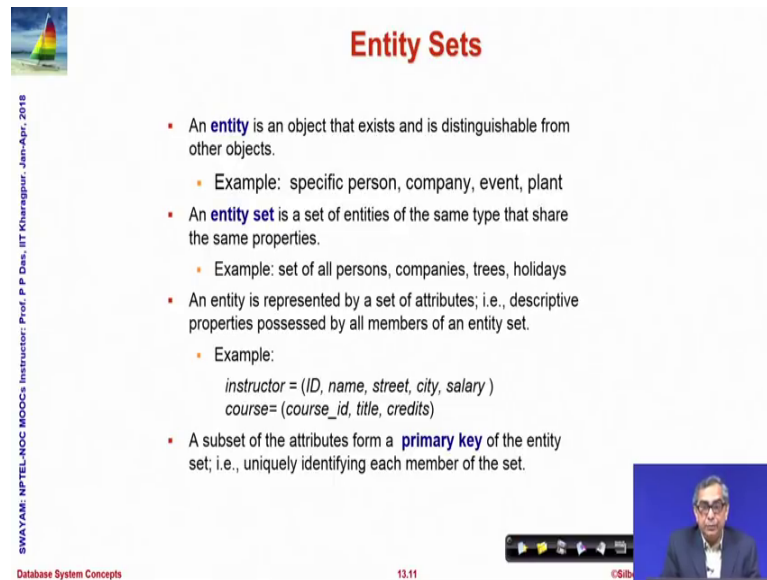
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Database System Concepts 13.10 ©Gib

Get the overall logical structure it is useful in mapping the meaning and interactions of the real world in terms of certain diagrammatic schemas and it employs 3 basic concepts entities or entity sets we talked about entities, all entities that share the same set of properties like if student is an entity, then the collection of student is an entity set a instructor is an entity collection of instructors is an entity set.

So, all entities in an entity set will share the same set of attributes, will have relationship sets which define relationship between multiple entity sets and certainly in the process will use make use of attributes. These are the 3 key components of an ER model it also has a ER diagram as we will show soon.

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The slide is titled "Entity Sets" in red. It contains a list of three main points, each with a sub-point example. The first point defines an entity as a distinguishable object, with examples like a person or company. The second point defines an entity set as a collection of objects of the same type, with examples like all persons or companies. The third point states that an entity is represented by a set of attributes, with examples for an instructor (ID, name, street, city, salary) and a course (course_id, title, credits). The fourth point states that a subset of attributes forms a primary key, which uniquely identifies each member of the set. On the left side, there is a vertical text: "SWAYAM NPTEL-NOC MOOCs Instructor: Prof. P. P. Das, IIT Kharagpur, Jan-Apr, 2018". At the bottom left, it says "Database System Concepts". At the bottom center, it says "13.11". At the bottom right, there is a small video inset of a man speaking and a copyright notice "©Silb".

Entity Sets

- An **entity** is an object that exists and is distinguishable from other objects.
 - Example: specific person, company, event, plant
- An **entity set** is a set of entities of the same type that share the same properties.
 - Example: set of all persons, companies, trees, holidays
- An entity is represented by a set of attributes; i.e., descriptive properties possessed by all members of an entity set.
 - Example:
instructor = (ID, name, street, city, salary)
course = (course_id, title, credits)
- A subset of the attributes form a **primary key** of the entity set; i.e., uniquely identifying each member of the set.

So, as already defined entity is an object that exist and is distinguishable from other objects, entity set is a set of entities of the same type that share the same properties and an entities is represented by the set of attributes or properties that describe it.

So, when we say instructive for example, if we say here these are my attributes you have already learned this in terms of studying SQL. So, it has there is 5 attributes and these 5 attributes together or the values of these 5 attributes for a particular instructor defines my entity set instructor, collection of these attributes define my entity set courses. So, these are my different entity sets that exist that can be defined.

So, a subset of attributes in the entity set forms a key called the primary key, which can uniquely identify every entity in that entity set we have already been familiar with this concept of primary key the same concept continues.

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Entity Sets – instructor and student

instructor_ID	instructor_name
76766	Crick
45565	Katz
10101	Srinivasan
98345	Kim
76543	Singh
22222	Einstein

instructor

student-ID	student_name
98988	Tanaka
12345	Shankar
00128	Zhang
76543	Brown
76653	Aoi
23121	Chavez
44553	Peltier

student

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So, these are examples of entity sets instructor with 2 attributes and student with 2 attributes as well.

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Relationship Sets

- A **relationship** is an association among several entities

Example:

44553 (Peltier)	<i>advisor</i>	22222 (Einstein)
student entity	relationship set	instructor entity

- A **relationship set** is a mathematical relation among $n \geq 2$ entities, each taken from entity sets

$$\{(e_1, e_2, \dots, e_n) \mid e_1 \in E_1, e_2 \in E_2, \dots, e_n \in E_n\}$$

where (e_1, e_2, \dots, e_n) is a relationship

- Example:
 $(44553, 22222) \in \text{advisor}$

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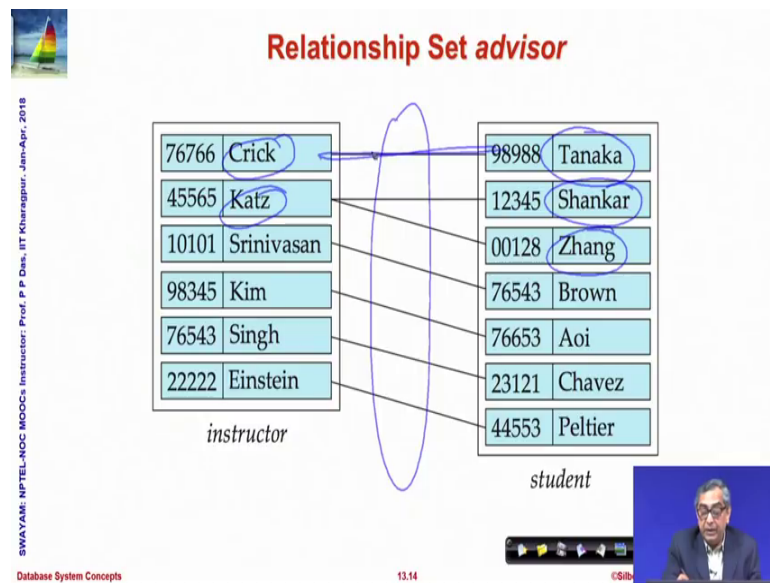
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A relationship is an association among two or more entities, so here we have an entity here shown as a student this is a student entity, identified by the student id which is a primary key in the student entity set. We have an instance of an instructor entity identified by the id of the instructor Einstein, which identifies any instructor uniquely and then adviser is a relationship set which relates these 2.

So, what I we want to mean is if I say adviser relates 445532 2222, what I want to mean is peltier the student peltier is advised by the instructor Einstein. So, whenever we relate two or more entity sets like this we get relationships. So, a relationship is a mathematical relation Emma more than two or more entities, each taken from the entity set.

So, you can see that it can have components $e_1 e_2 e_n, n$ entity sets and each entity e_1 should belong to entity set capital E_1 , e_2 should belong to entity set capital E_2 and so on and is called a relationship we have already seen the advisor relationship as above.

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So, here what we show is a relationship advisor by these arrows these lines. So, what we are showing is this connection between these 2, show that this student is advised by this instructor where as you can see. So, crick advises Tanaka where as Shankar and Zhang both are advised by Katz.

So, this group of associations between instructor and student is the gives me the relationship adviser as to who advises whom.

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Relationship Sets (Cont.)

- An attribute can also be associated with a relationship set.
- For instance, the *advisor* relationship set between entity sets *instructor* and *student* may have the attribute *date* which tracks when the student started being associated with the advisor

instructor	date	student
76766 Crick	3 May 2008	98988 Tanaka
45565 Katz	10 June 2007	12345 Shankar
10101 Srinivasan	12 June 2006	00128 Zhang
98345 Kim	6 June 2009	76543 Brown
76543 Singh	30 June 2007	76653 Aoi
22222 Einstein	31 May 2007	23121 Chavez
	4 May 2006	44553 Peltier

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A relationship also like the entity sets the relationship also can have some additional attribute. For example, when I say that crick advises Tanaka I may associate an attribute date type attribute set third May 2018, to mean that when did this process of crick advising Tanaka started, we can it can be some other attribute also.

So, all that I am trying to highlight is attributes can be assigned to relationships as well.

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Degree of a Relationship Set

- Binary relationship
 - involve two entity sets (or degree two).
 - most relationship sets in a database system are binary.
- Relationships between more than two entity sets are rare. Most relationships are binary. (More on this later.)
 - Example: *students* work on research *projects* under the guidance of an *instructor*.
 - relationship *proj_guide* is a ternary relationship between *instructor*, *student*, and *project*

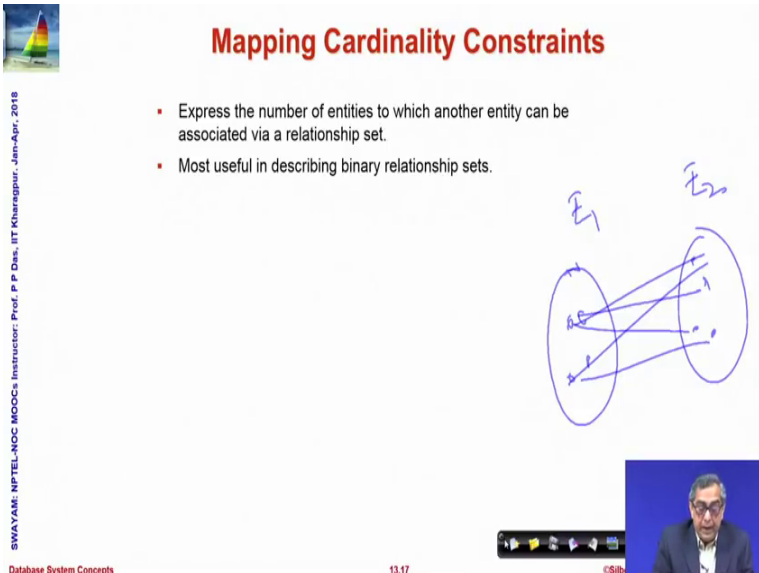
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Now, how will a relationship span out, we have said that a relationship must involve 2 entity sets. So, primarily relationships are binary it involves 2 and most relationships in

most databases are binary in nature, but it could be that there are we will see later that there are possibilities of having relationships which are more than binary ternary and higher.

So, here are example students works on research projects under the guidance of an instructor. So, here we have as you can see student's research projects and instructors, so there are 3 entity sets. So, if I want to maintain a relationship of say project guidance between them then that turns out to be a ternary relationship we will talk about this more later.

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Mapping Cardinality Constraints

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

The diagram shows two entity sets, E_1 and E_2 , represented as ovals. E_1 contains three elements and E_2 contains two elements. Arrows indicate a many-to-many relationship between the two sets.

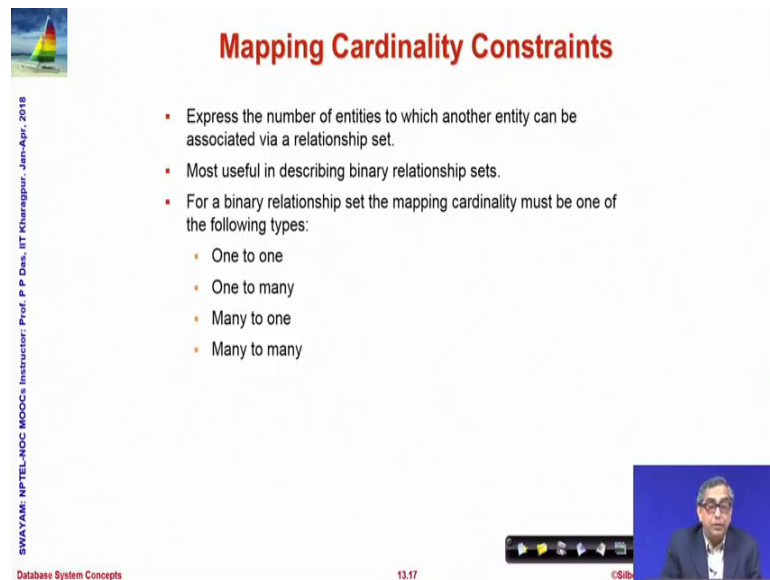
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There are constraints in terms of the cardinality of the relationship, the cardinality basically talks of that when we have when I have a relation entity set E_1 and identity set E_2 .

So, there are different entities in them and I have different associations between them, then the question is how many of the entity of one entity set is related to how many of the entities of the other entity set and certain types of cardinality measures are very important.

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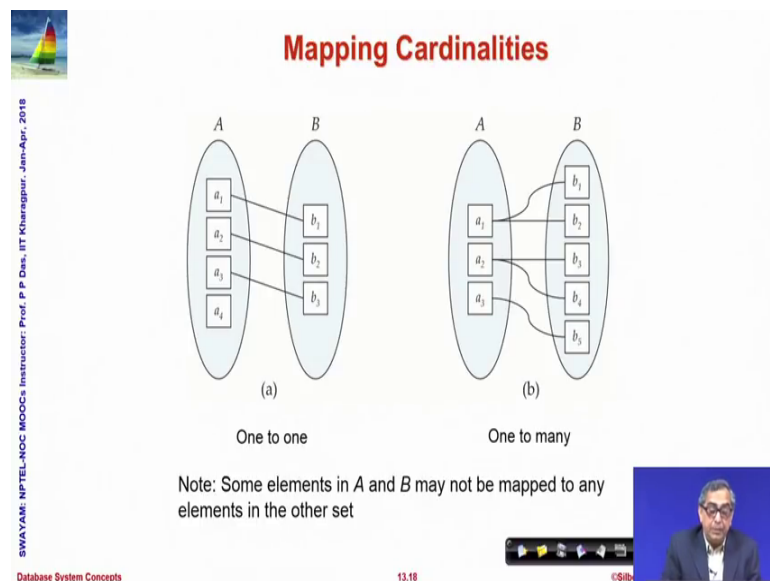
Mapping Cardinality Constraints

- Express the number of entities to which another entity can be associated via a relationship set.
- Most useful in describing binary relationship sets.
- For a binary relationship set the mapping cardinality must be one of the following types:
 - One to one
 - One to many
 - Many to one
 - Many to many

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To track and we say it is whether it is 1 to 1 to many many to one or many to many.

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Mapping Cardinalities

(a) One to one

(b) One to many

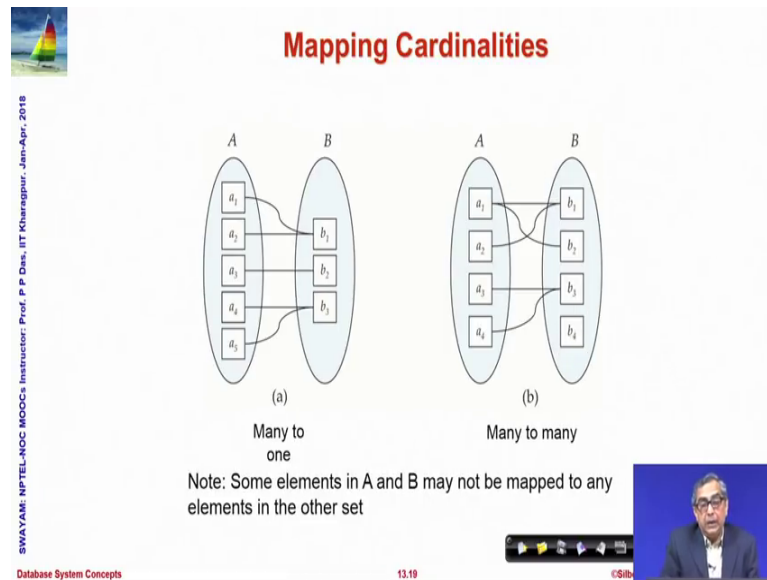
Note: Some elements in A and B may not be mapped to any elements in the other set

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So, here the examples or the schematics, so in the first one in the diagram A you see that every entity from the entity set A relates to exactly one entity in the entity set B or you can say at most one entity in then they decide B similarly every entity in entity set B relates to exactly one entity in entity set A or at most 1 entity and entity set a if this holds then we say this relationship is one to one whereas, in diagram B you see that a 1 relates to b 1 as well as b 2 a 2 relates to b 3 as well as b4.

So, 1 entity in A relates to more than 1 entity may relate to more than 1 entity in B, but if you look from B side every entity in B is related to at most 1 entity in A then we say from A to B it is 1 to many.

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Now naturally since I can put the relations in any order as we have one to many if you look in the other direction it becomes many to 1. So, many to one is from A to B many to one is where more than one entity in set A may relate to one entity inside B, but all entities in set B relates to at most one entity inside A and when there is no restriction at all that is any number of entities in set A may relate to any number of entities inside B and any number of entities in set B may relate to any number of entities in set A we say it is a many to many relation.

So, we have one too many one to one, we have one too many and many to one and we have many to many and it often helps in the design to be able to characterize which type of relationship we do have.

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Complex Attributes

- Attribute types:
 - Simple and composite attributes.
 - Single-valued and multivalued attributes
 - Example: multivalued attribute: *phone_numbers*
 - Derived attributes
 - Can be computed from other attributes
 - Example: age, given *date_of_birth*
 - Domain – the set of permitted values for each attribute

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Coming to the attributes we can note that attributes are of different types, one is they could be simple or composite a simple attribute is just one single domain value like a salary number like an id like a name string and so on; whereas, a composite attribute may comprise of multiple parts.

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Composite Attributes

composite attributes: *name*, *address*

component attributes: *first_name*, *middle_initial*, *last_name*, *street*, *city*, *state*, *postal_code*, *street_number*, *street_name*, *apartment_number*

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So consider this, this is a composite attribute, so name is an attribute if I think of then it has different parts, it is a first name middle name last name if I think of address it has. So, many different parts then street itself has so many different parts. So, whenever an

attribute is comprised some more of the components, when it is not a simple value then it is called a composite attribute we will see how to handle them; then some attributes may be single valued, for example a person has a has 1 name let us say, but has one address, but may have 2 or more phone numbers, the attributes which can take more than 1 value is known to be multi valued attribute.

So, we also need to specify whether certain specifying in the design whether certain attributes are single valued or multiple valued multi valued; of course, single value attributes are easy to deal with if it is multi valued we need to do some design changes. Certain attributes can be derived for example age, now I cannot keep the age of some a person in the database because, with every day the age changes. So, what we typically keep is a date of birth and the age is computed on the day when the particular query is made to find out what the age is so it is called a derived attribute and each 1 of them will have corresponding set of domains.

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Redundant Attributes

- Suppose we have entity sets:
 - instructor, with attributes: *ID, name, dept_name, salary*
 - department, with attributes: *dept_name, building, budget*

inst_dept

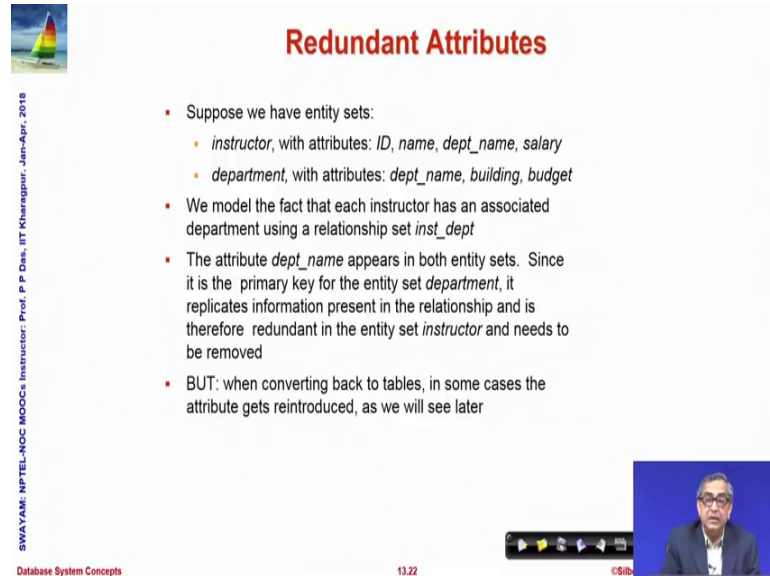
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Some attributes in the design may turn out to be redundant also consider this you have already seen this this is an instructor, which has a department name along with the different attributes and certainly I have a department table, so which department relation which gives the details of the department. Now since every instructor belongs to a department, so naturally we might want to have a relation in department which could give the instructor and his or her department name. So, if we maintain that then this

becomes a redundant attribute this is not required, because if that information is already there in this relation.

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Redundant Attributes

- Suppose we have entity sets:
 - *instructor*, with attributes: *ID*, *name*, *dept_name*, *salary*
 - *department*, with attributes: *dept_name*, *building*, *budget*
- We model the fact that each instructor has an associated department using a relationship set *inst_dept*
- The attribute *dept_name* appears in both entity sets. Since it is the primary key for the entity set *department*, it replicates information present in the relationship and is therefore redundant in the entity set *instructor* and needs to be removed
- BUT: when converting back to tables, in some cases the attribute gets reintroduced, as we will see later

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So, in several cases there is a question of whether we maintain some information in terms of a relation or we can make that directly include that directly in the entity set and get rid of that relation. So, if I have the inch depth relation and then the attribute department name appears on both these sets, inst dept as well as on the instructor and there is duplication replication of the data which we want to avoid. But we will see the different cases when which style of design, whether we would be better to maintain the department name as a part of the instructor relation or it would be better not to have it there and have a separate relation which maps instructor id against the department name.

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Weak Entity Sets *Sec - course (course_id, sec_id ...)*

- Consider a *section* entity, which is uniquely identified by a *course_id*, *semester*, *year*, and *sec_id*.
- Clearly, section entities are related to course entities. Suppose we create a relationship set *sec_course* between entity sets *section* and *course*.
- Note that the information in *sec_course* is redundant, since *section* already has an attribute *course_id*, which identifies the course with which the section is related.
- One option to deal with this redundancy is to get rid of the relationship *sec_course*; however, by doing so the relationship between *section* and *course* becomes implicit in an attribute, which is not desirable.

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Finally comes a concept of weak entity sets you need to understand this a little bit, consider the university database example. So, we have courses we have students we have instructors and we have section, a section is if a course is large then it needs to be taught in multiple sections. So, for the same course at the same semester in the same year I may have different sections, in which the students are divided and naturally there could be multiple instructors each teaching 1 section of that course and students will be distributed on the sections not on the course.

Now, consider this section entity, if you look into this then this is how what we we maintained we did a course id semester year and section id, but if you look into specifically and if you want to know know you know that there is a section and there is a course. So, you may want to relate these 2 section with the course and set up an entity between them. So, what will it relate it will relate the course id of the course with all of these, but the course id is already there as a part of the section right. So, you would say that well it is not required to have the course id, since it already has that and it identifies it.

So, we can can we remove this course id from here, well if we remove the course id now we have a different problem. If you remove the course id then you have section id semester and year. But this does not uniquely represent the tuples of this relation

because, there could be 2 section as in the same semester in the same year for 2 different courses how do you distinguish them.

So, you get into a situation where the course the section gets identified uniquely provided, either you know the relationship between the section and the course in terms of the sec course relationship or you include the primary key of course, into the relation section which we did in the design and this is not a coincidence this is something which happens regularly and is is the characteristics that specify the existence of weak entity sets.

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Weak Entity Sets (Cont.)

- An alternative way to deal with this redundancy is to not store the attribute *course_id* in the *section* entity and to only store the remaining attributes *section_id*, *year*, and *semester*. However, the entity set *section* then does not have enough attributes to identify a particular *section* entity uniquely; although each *section* entity is distinct, sections for different courses may share the same *section_id*, *year*, and *semester*.
- To deal with this problem, we treat the relationship *sec_course* as a special relationship that provides extra information, in this case, the *course_id*, required to identify *section* entities uniquely.
- The notion of **weak entity set** formalizes the above intuition. A weak entity set is one whose existence is dependent on another entity, called its **identifying entity**; instead of associating a primary key with a weak entity, we use the identifying entity, along with extra attributes called **discriminator** to uniquely identify a weak entity. An entity set that is not a weak entity set is termed a **strong entity set**.

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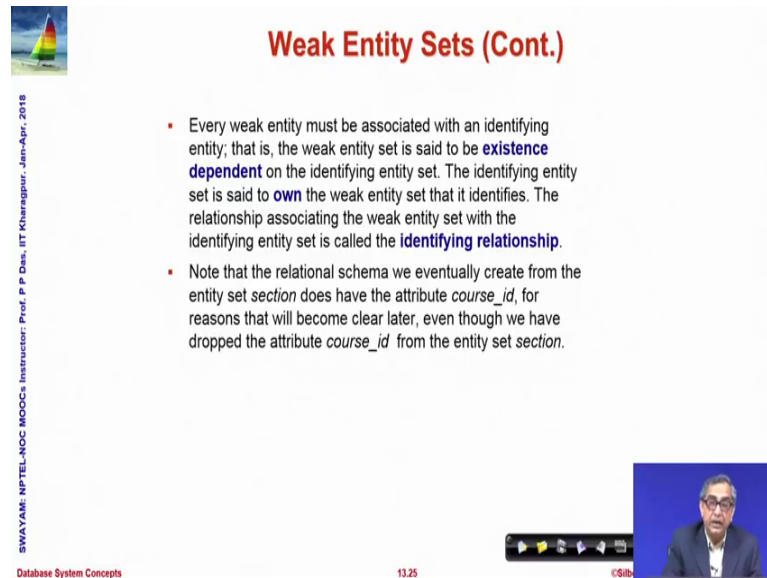
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So, the weak entity set is one whose existence depends on another entity set. So, if I just say section having section id year and semester then it is not uniquely specified, until I have a relation section course which relates the section to the particular course id. When such relationships are used to identify entities of a particular entity set, then the unique side the course side which is unique is known as the identifying entity and the other attributes in this case section id year semester are known as the discriminators.

So, we have a relationship between a weak entity set which is section, we have a strong entity set which is course why is it strong because course is identified by course id itself. Section is not unless you have a set course kind of relationship set between the course and the section which specifies that well, for this course this is the section this is the year this is the semester. So, this is the identifying entity through which the entities of this set

gets specified and whenever that situation happens then we say that we have a weak entity set.

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Weak Entity Sets (Cont.)

- Every weak entity must be associated with an identifying entity; that is, the weak entity set is said to be **existence dependent** on the identifying entity set. The identifying entity set is said to **own** the weak entity set that it identifies. The relationship associating the weak entity set with the identifying entity set is called the **identifying relationship**.
- Note that the relational schema we eventually create from the entity set *section* does have the attribute *course_id*, for reasons that will become clear later, even though we have dropped the attribute *course_id* from the entity set *section*.

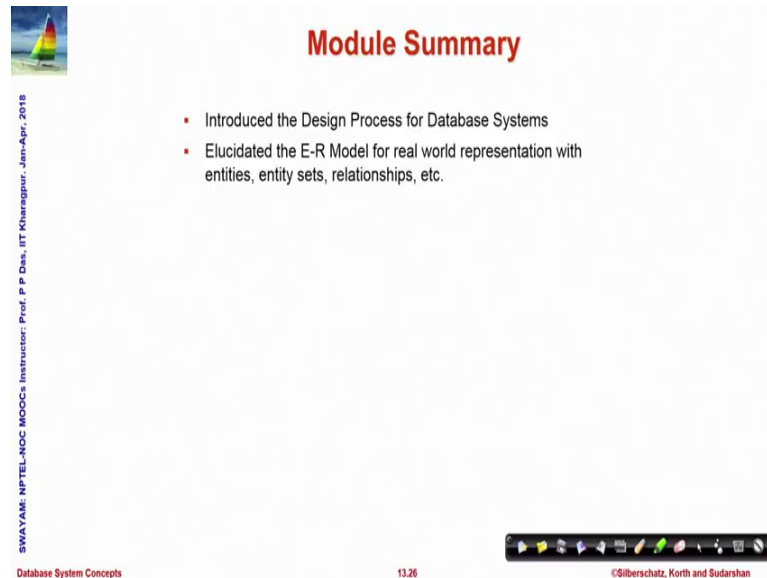
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So, weak entity sets naturally cannot happen by themselves their existence dependent on identifying entity set and the identifying entity set owns the weak entity set. So, the courses in that way own the section and the identifying relationship between them is necessary to uniquely identify every entity of this weak entity set or section in our case.

So, this notion is very important for the design as we will see that the relational schema that we eventually created, in this case from the entity set section we did include course id as a part of the primary key not using the sec course kind of relationship and we will show how this design style for dealing with entity weak entity sets influences the different database designs. So, weak entity sets are critical notions that you need to be aware of need to be confident of.

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Module Summary

- Introduced the Design Process for Database Systems
- Elucidated the E-R Model for real world representation with entities, entity sets, relationships, etc.

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So, in summary we have introduced the design process for database systems I will just quickly recap, the first stage is identifying the data items which is leading to the conceptual design, which will primarily do in terms of the entity relationship model identifying the entities the entity sets, the attributes that define the entity set, describe the entity set, the subset of attributes forming primary key that uniquely specifies every entity set, every entity in the entity set and the relationships typically binary may be non binary also, relationships that hold between the different entity sets.

So, this is the conceptual design that will lead to more detail logical design of how the relationship should be organized, what is the cardinality of that, what kind of attributes do I have, whether it is sample whether it is composite whether certain attributes are derived or not. So, all those are different aspects will have to be detailed out and we need to identify what are the weak entity sets and what are the strong entity sets, what are the identifying entities and with that we could complete the logical design and then we will need to make it in terms of it express it in terms of a relational schema.

So, in this module we have just taken a look in the first part the entity relationship model and the very basic of how the conceptual design. We will go forward, in the model we have seen all the different primitives required to represent the reality represent what holds in the real world.