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CSE3203 - Software Engineering and Information System Design

Chapter 9

– Data Modeling

Chapter Outline

- Data Modeling
  - Entity
  - Relationships
  - ERD
  - Degree of Relationships
  - Cardinalities
  - Selecting Best Alternative Design Strategy

Lecture 17

Data Modeling

- Overview of Database Design
- The Entity-Relationship model
- ER Model Basics
- Degree of a relationship
- Strong versus Weak entity type
- Simple versus composite attributes
- Single-Valued versus Multivalued Attribute
- Entity vs. Attribute
- Entity vs. Relationship
- Binary vs. Ternary Relationships

Overview of Database Design

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- Requirements Analysis: Understand what data will be stored in the database, and the operations it will be subject to.
- Conceptual Design: (ER Model is used at this stage.)
  - What are the entities and relationships in the enterprise?
  - What information about these entities and relationships should we store in the database?
  - What are the integrity constraints or business rules that hold?
- Logical Design: Convert the conceptual database design into the data model underlying the DBMS chosen for the application.
- Schema Refinement: (Normalization) Check relational schema for redundancies and anomalies.
- Physical Database Design and Tuning: Consider typical workloads and further refinement of the database design (v.g. build indices).
- Application and Security Design: Consider aspects of the application beyond data. Methodologies like UML often used for addressing the complete software development cycle.

The Entity-Relationship model

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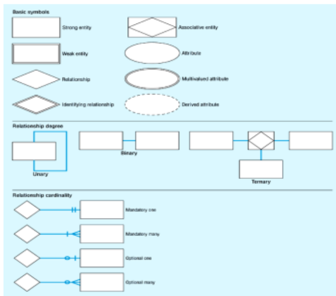
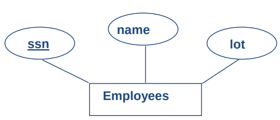
- The E-R model is a detailed, logical representation of the data for an organisation or business area
- It should be understandable to both the user and to the IT technologist
- The model must be as 'open' as possible and not tied to any technology or to any particular business methodology
- It must be flexible enough so that it can be used and understood in practically any environment where information is modelled
- It is expressed in terms of entities in the business environment, the relationships (or associations) among those entities and the attributes (properties) of both the entities and their relationships
- The E-R model is usually expressed as an E-R diagram

ER Model Basics: Notation



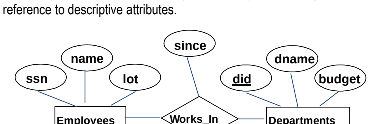
ER Model Basics (Contd.)

- Entity: Real-world object distinguishable from other objects. An entity is described using a set of attributes.
- Entity Set: A collection of entities of the same kind. E.g., all employees.
  - All entities in an entity set have the same set of attributes.
  - Each entity set has a key(a set of attributes uniquely identifying an entity).
  - Each attribute has a domain.



ER Model Basics (Contd.)

- Relationship: Association among two or more entities. E.g., Peter works in Pharmacy department.
- Relationship Set: Collection of similar relationships.
  - An **n-ary** relationship set R relates n entity sets E1 ... En; each relationship in R involves entities e1 $\in$ E1, ..., en $\in$ En
  - Same entity set could participate in different relationship sets, or in different "roles" in same set.
  - Relationship sets can also have descriptive attributes (e.g., the since attribute of Works_In). A relationship is uniquely identified by participating entities without reference to descriptive attributes.

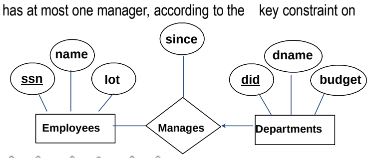


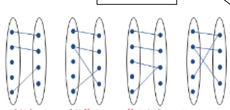
Attributes

- An attribute is a property or characteristic of an entity type, for example the entity EMPLOYEE may have attributes Employee_Name and Employee_Address.
- In ER diagrams place attributes name in an ellipse with a line connecting it to its associated entity
- Attributes may also be associated with relationships
- An attribute is associated with exactly one entity or relationship

Cardinality

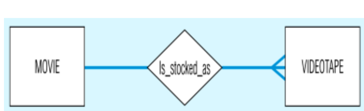
- Consider Works_In (in previous slide): An employee can work in many departments; a dept can have many employees.
- In contrast, each dept has at most one manager, according to the key constraint on Manages.





Cardinality constraints

- The number of instances of one entity that can or must be associated with each instance of another entity.
- If we have two entity types A and B, the cardinality constraint specifies the number of instances of entity B that can (or must) be associated with entity A
- e.g. a video store may stock more than one VIDEOTAPE for each MOVIE, this is a 'one-to-many' relationship as in the following Fig.



Minimum cardinality

- Yet there may be a more precise way of saying this
- The minimum cardinality of a relationship is the minimum number of instances of an entity B that may be associated with each instance of an entity A
- In our example, the minimum number of VIDEOTAPES of a MOVIE is zero (entity B is an optional participant in the 'Is_Stocked_As' relationship)
- This is signified by the symbol zero through the arrow near the VIDEOTAPE entity in the following Fig.

Maximum cardinality

- Is the maximum number of instances of an entity B that may be associated with each instance of entity A
- In the following Fig., the maximum cardinality for the VIDEOTAPE entity type is 'many' (an unspecified number greater than 1)
- This is indicated by the 'crow's foot' symbol on the arrow next to the VIDEOTAPE entity symbol

Degree of a relationship

- Is the number of entity types that participate in it.
- Thus 'Completes' has degree 2, since there are two participating entity types, EMPLOYEE and COURSE
- The three most common relationship degrees are unary (degree 1), binary (degree 2) and ternary (degree 3 –see following Fig.)
- Higher degree relationships are possible but rarely encountered in practice

Unary relationship

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- Is between the instances of a single entity type (also called recursive relationships)
- 'Is_Married_To' is a one-to-one relationship between instances of the PERSON entity type
- 'Manages' is a one-to-many relationship between instances of the EMPLOYEE entity type

Binary relationships

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- Between the instances of two entity types, and is the most common type of relationship encountered in data modelling. e.g. (one-to-one) an EMPLOYEE is assigned one PARKING_PLACE, and each PARKING_PLACE is assigned to one EMPLOYEE
- e.g. (one to many) a PRODUCT_LINE may contain many PRODUCTS, and each PRODUCT belongs to only one PRODUCT_LINE
- e.g. (many-to-many) a STUDENT may register for more than one COURSE, and each COURSE may have many STUDENTS

Ternary relationships

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- A ternary relationship is a simultaneous relationship among the instances of 3 entity types
- It is the most common relationship encountered in data modelling
- The following Fig. shows a typical ternary relationship
- Here, vendors can supply various parts to warehouses

Ternary relationships

- The relationship 'Supplies' is used to record the specific PARTs supplied by a given VENDOR to a particular WAREHOUSE
- There are two attributes on the relationship 'Supplies', Shipping_Mode and Unit_Cost
- e.g. one instance of 'Supplies might record that VENDOR X can ship PART C to WAREHOUSE Y, that the Shipping_Mode is 'next_day_air' and the Unit_Cost is £5-00 per unit

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An example using a ternary relationship

- PART and WAREHOUSE are mandatory participants in the relationship, whilst VENDOR is an optional participant
- The cardinality of each of the participating entities is mandatory one, since each SUPPLY_SCHEDULE instance must be related to exactly one instance of each of these participating entity types
- Each VENDOR can supply many PARTs to any number of WAREHOUSES, but need not supply any parts
- Each PART can be supplied by any number of VENDORs to more than one WAREHOUSE, but each part must be supplied by at least one vendor to a warehouse
- Each WAREHOUSE can be supplied with any number of PARTS from more than one VENDOR, but each warehouse must be supplied with at least one part

Ternary relationships

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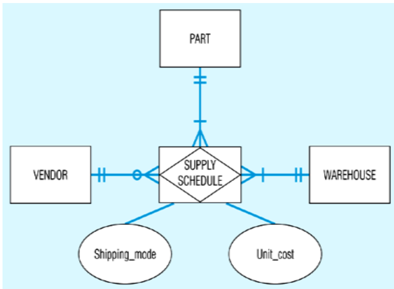

Ternary relationships

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- We do not use diamond symbols on the lines from SUPPLY_SCHEDULE to the three entities, because these lines do not represent binary relationships
- It is recommended that all ternary (or higher) relationships are converted into associative entities (as in the Fig.), as it makes the representation of participation constraints (discussed later) easier
- Many CASE tools cannot represent ternary relationships, so you must represent the ternary relationship with an associative entity and three binary relationships

Sample E-R Diagram

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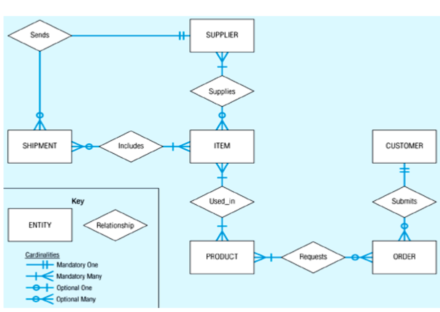

Strong versus Weak entity type

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- Most of the basic entity types are classified as strong entity types [Rectangle] – one that exists independently from other entity types (such as EMPLOYEE)
- Always have a unique characteristic (identifier) – an attribute or combination of attributes that uniquely distinguish each occurrence of that identity
- A weak entity type [[Double Rectangle]] – existence depends on some other entity type. It has no meaning in the ER diagram without the entity on which it depends (such as DEPENDENT)
- The entity type on which the weak entity type depends is called the Identifying owner (or owner for short).
- Identifying relationship is the relationship between a weak entity type and and its owner (such as 'Has' in the following Fig.)
- Weak entity identifier is its partial identifier (double underline) combined with that of its owner. During a later design stage dependent name will be combined with Employee_ID (the identifier of the owner) to form a full identifier for DEPENDENT.

Example of a weak entity

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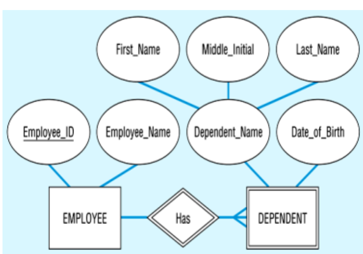

Simple versus composite attributes

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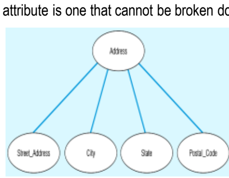
- Some attributes can be broken down into meaningful component parts, such as Address, which can be broken down into Street_Address, City..etc.
- The component attributes may appear above or below the composite attribute on an ER diagram
- Provide flexibility to users, as can refer to it as a single unit or to the individual components
- A simple (atomic) attribute is one that cannot be broken down into smaller components



Single-Valued versus Multivalued Attribute

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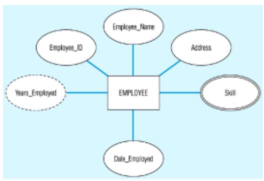
- It frequently happens that there is an attribute that may have more than one value for a given instance, e.g. EMPLOYEE may have more than one Skill.
- A multivalued attribute is one that may take on more than one value – it is represented by an ellipse with double lines



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ISA (`is a') Hierarchies

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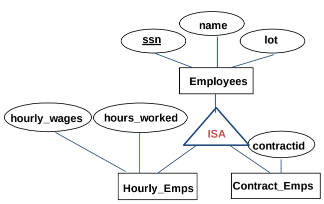
- If we declare A **ISA** B, every A entity is also considered to be a B entity.



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Entity vs. Attribute

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- Should address be an attribute of Employees or an entity (connected to Employees by a relationship)?
- Depends upon the use we want to make of address information, and the semantics of the data:
  - If we have several addresses per employee, address must be an entity (since attributes cannot be set-valued).
  - If the structure (city, street, etc.) is important, e.g., we want to retrieve employees in a given city, address must be modeled as an entity (since attribute values are atomic).

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Entity vs. Attribute (Contd.)

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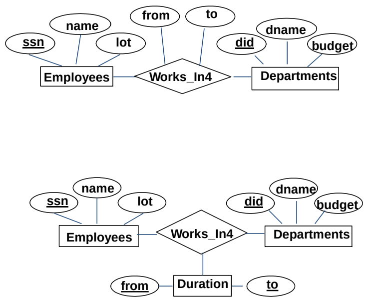
- Works_In4 does not allow an employee to work in a department for two or more periods (a relationship is identified by participating entities).
- Similar to the problem of wanting to record several addresses for an employee: We want to record several values of the descriptive attributes for each instance of this relationship. Accomplished by introducing new entity set, Duration.



Entity vs. Relationship

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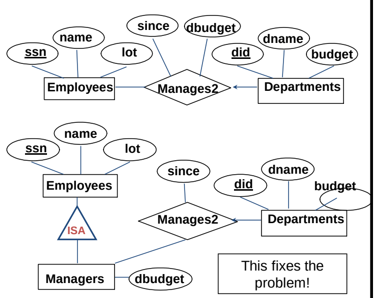
- First ER diagram OK if a manager gets a separate discretionary budget for each dept.
- What if a manager gets a discretionary budget that covers all managed depts?
  - Redundancy: dbudget stored for each dept managed by manager.
  - Misleading: Suggests dbudget associated with department-mgr combination.



Binary vs. Ternary Relationships

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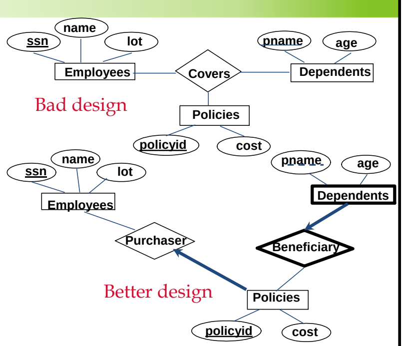
- Suppose:
  - A policy cannot be owned by more than one employee.
  - Every policy must be owned by some employee.
  - Dependent is a weak entity set, identified by policyId.



Binary vs. Ternary Relationships (Contd.)

- Previous example illustrated a case when two binary relationships were better than one ternary relationship.
- An example in the other direction: a ternary relation Contracts relates entity sets Parts, Departments and Suppliers, and has descriptive attribute qty. No combination of binary relationships is an adequate substitute:
  - Although S "can-supply" P, D "needs" P, and D "deals-with" S, all these do not imply that D has agreed to buy P from S (because D could buy P from another supplier).

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Summary of Conceptual Design

- Conceptual design follows requirements analysis,
  - Yields a high-level description of data to be stored
- ER model popular for conceptual design
  - Constructs are expressive, close to the way people think about their applications.
- Basic constructs: entities, relationships, and attributes (of entities and relationships).
- Some additional constructs: weak entities, ISA hierarchies, and aggregation.
- Note: There are many variations on ER model.

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Summary of ER (Contd.)

- Several kinds of integrity constraints can be expressed in the ER model: key constraints, participation constraints, and overlap/covering constraints for ISA hierarchies. Some foreign key constraints are also implicit in the definition of a relationship set.
  - Some constraints (notably, functional dependencies) cannot be expressed in the ER model.
  - Constraints play an important role in determining the best database design for an enterprise.

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Summary of ER (Contd.)

- ER design is subjective. There are often many ways to model a given scenario! Analyzing alternatives can be tricky, especially for a large enterprise. Common choices include:
  - Entity vs. attribute, entity vs. relationship, binary or n-ary relationship, whether or not to use ISA hierarchies, and whether or not to use aggregation.
- Ensuring good database design: resulting relational schema should be analyzed and refined further. FD information and normalization techniques are especially useful.

THANK YOU