Introduction to Data Modeling

The Entity-Relationship Model

The Entity-Relationship (ER) model was originally proposed by Peter in 1976 [Chen76] as a way to unify the network and relational database views. Simply stated the ER model is a conceptual data model that views the real world as entities and relationships. A basic component of the model is the Entity-Relationship diagram which is used to visually represents data objects. Since Chen wrote his paper the model has been extended and today it is commonly used for database design For the database designer, the utility of the ER model is:

- it maps well to the relational model. The constructs used in the ER model can easily be transformed into relational tables.
- it is simple and easy to understand with a minimum of training. Therefore, the model can be used by the database designer to communicate the design to the end user.
- In addition, the model can be used as a design plan by the database developer to implement a data model in a specific database management software.

Basic Constructs of E-R Modeling

The ER model views the real world as a construct of entities and association between entities.

Entities

Entities are the principal data object about which information is to be collected. Entities are usually recognizable concepts, either concrete or abstract, such as person, places, things, or events which have relevance to the database. Some specific examples of entities are EMPLOYEES, PROJECTS, INVOICES. An entity is analogous to a table in the relational model.

Entities are classified as independent or dependent (in some methodologies, the terms used are strong and weak, respectively). An *independent entity* is one that does not rely on another for identification. A *dependent entity* is one that relies on another for identification.

An *entity occurrence* (also called an instance) is an individual occurrence of an entity. An occurrence is analogous to a row in the relational table.

Special Entity Types

Associative entities (also known as intersection entities) are entities used to associate two or more entities in order to reconcile a many-to-many relationship.

Subtypes entities are used in *generalization hierarchies* to represent a subset of instances of their parent entity, called the supertype, but which have attributes or relationships that apply only to the subset.

Associative entities and generalization hierarchies are discussed in more detail below.

Relationships

A Relationship represents an association between two or more entities. An example of a relationship would be:

employees are assigned to projects

projects have subtasks

departments manage one or more projects

Relationships are classified in terms of degree, connectivity, cardinality, and existence. These concepts will be discussed below.

Attributes

Attributes describe the entity of which they are associated. A particular instance of an attribute is a *value*. For example, "Jane R. Hathaway" is one value of the attribute Name. The *domain*of an attribute is the collection of all possible values an attribute can have. The domain of Name is a character string.

Attributes can be classified as identifiers or descriptors. Identifiers, more commonly called *keys*, uniquely identify an instance of an entity. A descriptor describes a non-unique characteristic of an entity instance.

Classifying Relationships

Relationships are classified by their degree, connectivity, cardinality, direction, type, and existence. Not all modeling methodologies use all these classifications.

Degree of a Relationship

The *degree of a relationship* is the number of entities associated with the relationship. The n-ary relationship is the general form for degree n. Special cases are the binary, and ternary ,where the degree is 2, and 3, respectively.

Binary relationships, the association between two entities is the most common type in the real world. A recursive binary relationship occurs when an entity is related to itself. An example might be "some employees are married to other employees".

A ternary relationship involves three entities and is used when a binary relationship is inadequate. Many modeling approaches recognize only binary relationships. Ternary or n-ary relationships are decomposed into two or more binary relationships.

Connectivity and Cardinality

The connectivity of a relationship describes the mapping of associated entity instances in the relationship. The values of connectivity are "one" or "many". The cardinality of a relationship is the actual number of related occurences for each of the two entities. The basic types of connectivity for relations are: one-to-one, one-to-many, and many-to-many.

A *one-to-one* (1:1) relationship is when at most one instance of a entity A is associated with one instance of entity B. For example, "employees in the company are each assigned their own office. For each employee there exists a unique office and for each office there exists a unique employee.

A *one-to-many* (1:N) relationships is when for one instance of entity A, there are zero, one, or many instances of entity B, but for one instance of entity B, there is only one instance of entity A. An example of a 1:N relationships is

a department has many employees

each employee is assigned to one department

A *many-to-many* (M:N) relationship, sometimes called non-specific, is when for one instance of entity A, there are zero, one, or many instances of entity B and for one instance of entity B there are zero, one, or many instances of entity A. An example is:

> employees can be assigned to no more than two projects at the same time;
>
> projects must have assigned at least three employees

A single employee can be assigned to many projects; conversely, a single project can have assigned to it many employee. Here the cardinality for the relationship between employees and projects is two and the cardinality between project and employee is three. Many-to-many relationships cannot be directly translated to relational tables but instead must be transformed into two or more one-to-many relationships using associative entities.

Direction

The direction of a relationship indicates the originating entity of a binary relationship. The entity from which a relationship originates is the *parent entity*; the entity where the relationship terminates is the *child entity*.

The direction of a relationship is determined by its connectivity. In a one-to-one relationship the direction is from the independent entity to a dependent entity. If both entities are independent, the direction is arbitrary. With one-to-many relationships, the entity occurring once is the parent. The direction of many-to-many relationships is arbitrary.

Type

An *identifying relationship* is one in which one of the child entities is also a dependent entity. A *non-identifying relationship* is one in which both entities are independent.

Existence

Existence denotes whether the existence of an entity instance is dependent upon the existence of another, related, entity instance. The existence of an entity in a relationship is defined as either *mandatory* or *optional*. If an instance of an entity must always occur for an entity to be included in a relationship, then it is mandatory. An example of mandatory existence is the statement "every project must be managed by a single department". If the instance of the entity is not required, it is optional. An example of optional existence is the statement, "employees may be assigned to work on projects".

Generalization Hierarchies

A generalization hierarchy is a form of abstraction that specifies that two or more entities that share common attributes can be generalized into a higher level entity type called a *supertype* or *generic* entity. The lower-level of entities become the *subtype*, or categories, to the supertype. Subtypes are dependent entities.

Generalization occurs when two or more entities represent categories of the same real-world object. For example, Wages_Employees and Classified_Employees represent categories of the same entity, Employees. In this example, Employees would be the supertype; Wages_Employees and Classified_Employees would be the subtypes.

Subtypes can be either mutually exclusive (disjoint) or overlapping (inclusive). A mutually exclusive category is when an entity instance can be in only one category. The above example is a mutually exclusive category. An employee can either be wages or classified but not both. An overlapping category is when an entity instance may be in two or more subtypes. An example would be a person who works for a university could also be a student at that same university. The completeness constraint requires that all instances of the subtype be represented in the supertype.

Generalization hierarchies can be nested. That is, a subtype of one hierarchy can be a supertype of another. The level of nesting is limited only by the constraint of simplicity. Subtype entities may be the parent entity in a relationship but not the child.

ER Notation

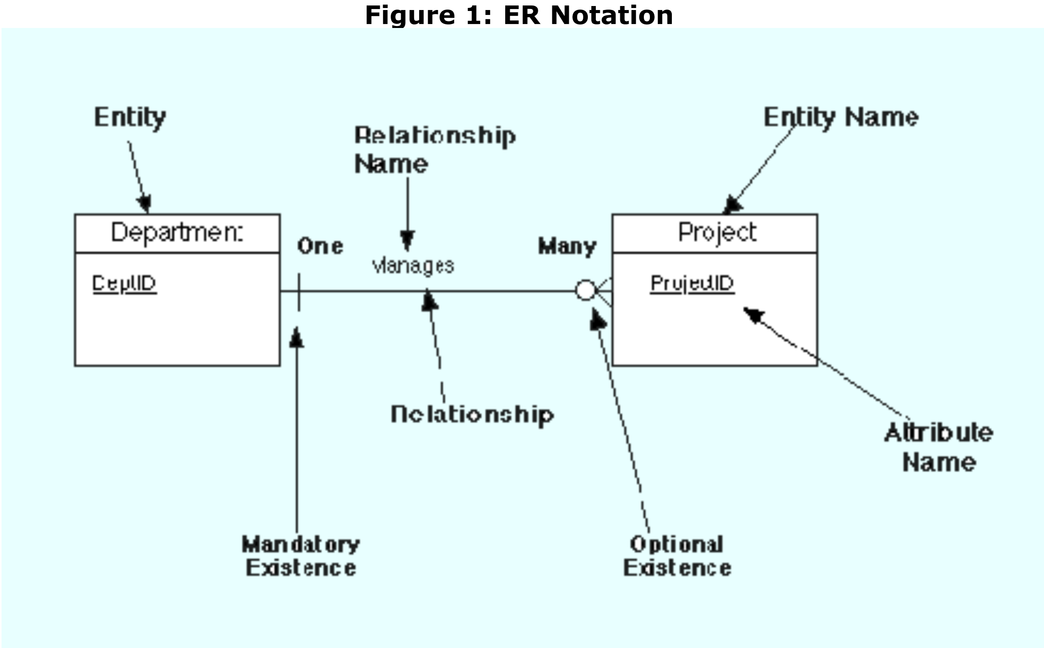
There is no standard for representing data objects in ER diagrams. Each modeling methodology uses its own notation. The original notation used by Chen is widely used in academics texts and journals but rarely seen in either CASE tools or publications by non-academics. Today, there are a number of notations used, among the more common are Bachman, crow's foot, and IDEFIX.

All notational styles represent entities as rectangular boxes and relationships as lines connecting boxes. Each style uses a special set of symbols to represent the cardinality of a connection. The notation used in this document is from Martin. The symbols used for the basic ER constructs are:

- entities are represented by labeled rectangles. The label is the name of the entity. Entity names should be singular nouns.
- relationships are represented by a solid line connecting two entities. The name of the relationship is written above the line. Relationship names should be verbs.
- attributes, when included, are listed inside the entity rectangle. Attributes which are identifiers are underlined. Attribute names should be singular nouns.
- cardinality of many is represented by a line ending in a crow's foot. If the crow's foot is omitted, the cardinality is one.
- existence is represented by placing a circle or a perpendicular bar on the line. Mandatory existence is shown by the bar (looks like a 1) next to the entity for an instance is required. Optional existence is shown by placing a circle next to the entity that is optional.

Examples of these symbols are shown in Figure 1 below:

Figure 1: ER Notation



Summary

The Entity-Relationship Model is a conceptual data model that views the real world as consisting of entities and relationships. The model visually represents these concepts by the Entity-Relationship diagram. The basic constructs of the ER model are entities, relationships, and attributes. Entities are concepts, real or abstract, about which information is collected. Relationships are associations between the entities. Attributes are properties which describe the entities. Next, we will look at the role of data modeling in the overall database design process and a method for building the data model. To proceed, see **Data Modeling As Part of Database Design**.

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