CHAPTER 6

Database Design using the E-R Model

Practice Exercises

6.1 Construct an E-R diagram for a car insurance company whose customers own one or more cars each. Each car has associated with it zero to any number of recorded accidents. Each insurance policy covers one or more cars and has one or more premium payments associated with it. Each payment is for a particular period of time, and has an associated due date, and the date when the payment was received.

Answer:

One possible E-R diagram is shown in Figure 6.101. Payments are modeled as weak entities since they are related to a specific policy.

Note that the participation of accident in the relationship *participated* is not total, since it is possible that there is an accident report where the participating car is unknown.

6.2 Consider a database that includes the entity sets *student*, *course*, and *section* from the university schema and that additionally records the marks that students receive in different exams of different sections.

a. Construct an E-R diagram that models exams as entities and uses a ternary relationship as part of the design.

b. Construct an alternative E-R diagram that uses only a binary relationship between *student* and *section*. Make sure that only one relationship exists between a particular *student* and *section* pair, yet you can represent the marks that a student gets in different exams.

Answer:

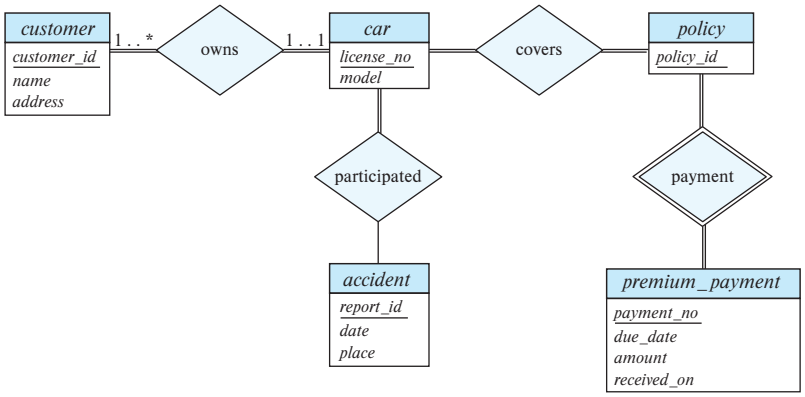


Figure 6.101 E-R diagram for a car insurance company.

a. The E-R diagram is shown in Figure 6.102. Note that an alternative is to model examinations as weak entities related to a section, rather than as strong entities. The marks relationship would then be a binary relationship between *student* and *exam*, without directly involving *section*.

b. The E-R diagram is shown in Figure 6.103. Note that here we have not modeled the name, place, and time of the exam as part of the relationship attributes. Doing so would result in duplication of the information, once per student, and we would not be able to record this information without an associated student. If we wish to represent this information, we need to retain a separate entity corresponding to each exam.

6.3 Design an E-R diagram for keeping track of the scoring statistics of your favorite sports team. You should store the matches played, the scores in each match, the players in each match, and individual player scoring statistics for each match.

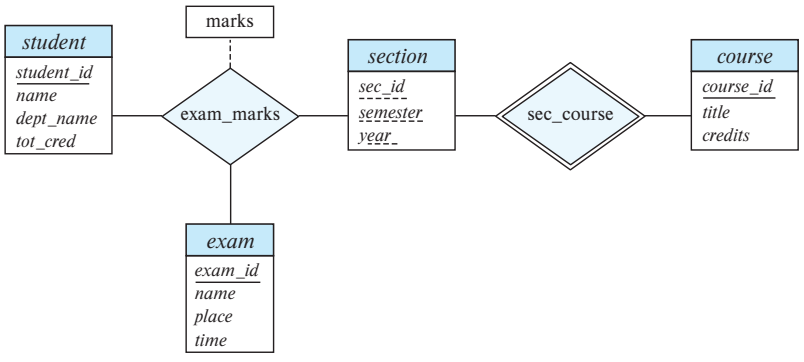


Figure 6.102 E-R diagram for marks database.

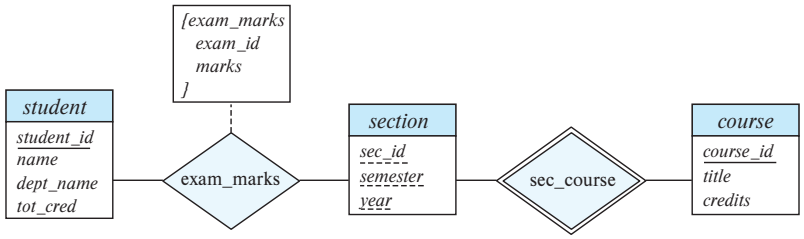


Figure 6.103 Another E-R diagram for marks database.

Summary statistics should be modeled as derived attributes with an explanation as to how they are computed.

Answer:

The diagram is shown in Figure 6.104. The derived attribute *season_score* is computed by summing the score values associated with the *player* entity set via the *played* relationship set.

6.4 Consider an E-R diagram in which the same entity set appears several times, with its attributes repeated in more than one occurrence. Why is allowing this redundancy a bad practice that one should avoid?

Answer:

The reason an entity set would appear more than once is if one is drawing a diagram that spans multiple pages.

The different occurrences of an entity set may have different sets of attributes, leading to an inconsistent diagram. Instead, the attributes of an entity set should be specified only once. All other occurrences of the entity should omit attributes. Since it is not possible to have an entity set without any attributes, an occurrence of an entity set without attributes clearly indicates that the attributes are specified elsewhere.

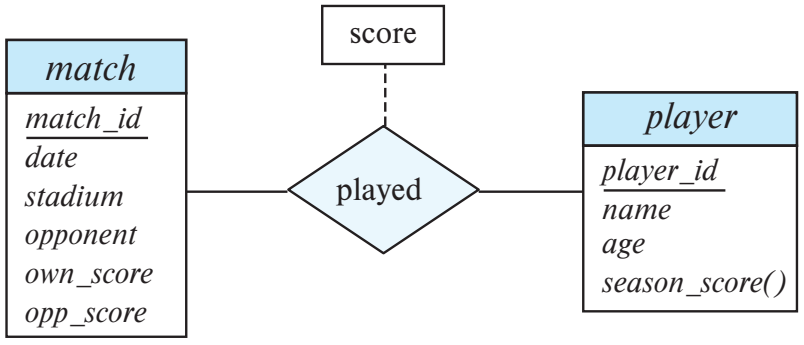


Figure 6.104 E-R diagram for favorite team statistics.

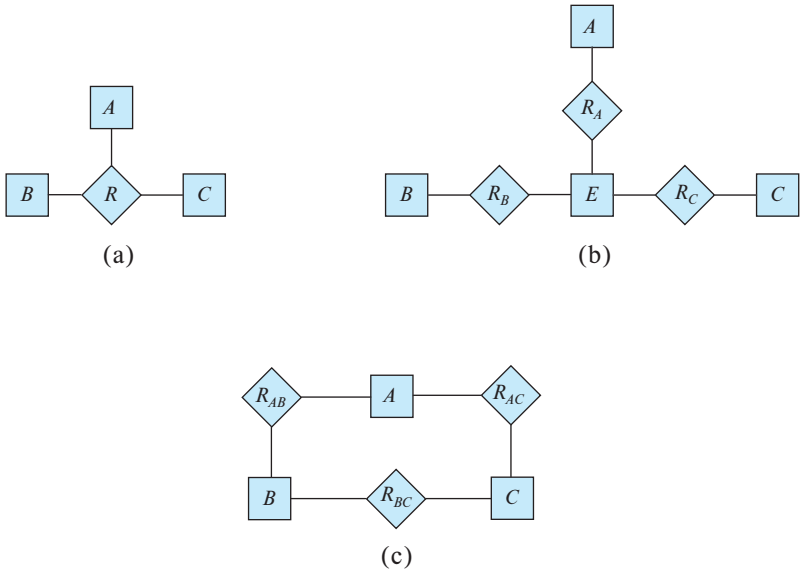


Figure 6.29 Representation of a ternary relationship using binary relationships.

6.5 An E-R diagram can be viewed as a graph. What do the following mean in terms of the structure of an enterprise schema?

a. The graph is disconnected.

b. The graph has a cycle.

Answer:

a. If a pair of entity sets are connected by a path in an E-R diagram, the entity sets are related, though perhaps indirectly. A disconnected graph implies that there are pairs of entity sets that are unrelated to each other. In an enterprise, we can say that the two parts of the enterprise are completely independent of each other. If we split the graph into connected components, we have, in effect, a separate database corresponding to each independent part of the enterprise.

b. As indicated in the answer to the previous part, a path in the graph between a pair of entity sets indicates a (possibly indirect) relationship between the two entity sets. If there is a cycle in the graph, then every pair of entity sets on the cycle are related to each other in at least two distinct ways. If the E-R diagram is acyclic, then there is a unique path between every pair of entity sets and thus a unique relationship between every pair of entity sets.

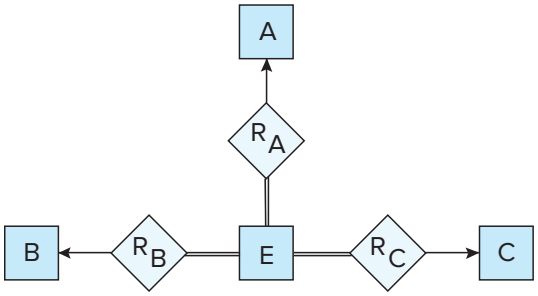


Figure 6.105 E-R diagram for Exercise Exercise 6.6b.

6.6 Consider the representation of the ternary relationship of Figure 6.29a using the binary relationships illustrated in Figure 6.29b (attributes not shown).

a. Show a simple instance of E, A, B, C, R_A, R_B, and R_C that cannot correspond to any instance of A, B, C, and R.

b. Modify the E-R diagram of Figure 6.29b to introduce constraints that will guarantee that any instance of E, A, B, C, R_A, R_B, and R_C that satisfies the constraints will correspond to an instance of A, B, C, and R.

c. Modify the preceding translation to handle total participation constraints on the ternary relationship.

Answer:

a. Let $E = \{e_1, e_2\}$, $A = \{a_1, a_2\}$, $B = \{b_1\}$, $C = \{c_1\}$, $R_A = \{(e_1, a_1), (e_2, a_2)\}$, $R_B = \{(e_1, b_1)\}$, and $R_C = \{(e_1, c_1)\}$. We see that because of the tuple (e_2, a_2), no instance of A, B, C, and R exists that corresponds to E, R_A, R_B and R_C.

b. See Figure 6.105. The idea is to introduce total participation constraints between E and the relationships R_A, R_B, R_C so that every tuple in E has a relationship with A, B, and C.

c. Suppose A totally participates in the relationhip R, then introduce a total participation constraint between A and R_A, and similarly for B and C.

6.7 A weak entity set can always be made into a strong entity set by adding to its attributes the primary-key attributes of its identifying entity set. Outline what sort of redundancy will result if we do so.

Answer:

The primary key of a weak entity set can be inferred from its relationship with the strong entity set. If we add primary-key attributes to the weak entity set, they will be present in both the entity set, and the relationship set and they have to be the same. Hence there will be redundancy.

6.8 Consider a relation such as *sec_course*, generated from a many-to-one relationship set *sec_course*. Do the primary and foreign key constraints created on the relation enforce the many-to-one cardinality constraint? Explain why.

Answer:
In this example, the primary key of *section* consists of the attributes (*course_id*, *sec_id*, *semester*, *year*), which would also be the primary key of *sec_course*, while *course_id* is a foreign key from *sec_course* referencing *course*. These constraints ensure that a particular *section* can only correspond to one *course*, and thus the many-to-one cardinality constraint is enforced.
However, these constraints cannot enforce a total participation constraint, since a course or a section may not participate in the *sec_course* relationship.

6.9 Suppose the *advisor* relationship set were one-to-one. What extra constraints are required on the relation *advisor* to ensure that the one-to-one cardinality constraint is enforced?

Answer:
In addition to declaring *s_ID* as primary key for *advisor*, we declare *i_ID* as a superkey for *advisor* (this can be done in SQL using the **unique** constraint on *i_ID*).

6.10 Consider a many-to-one relationship *R* between entity sets *A* and *B*. Suppose the relation created from *R* is combined with the relation created from *A*. In SQL, attributes participating in a foreign key constraint can be null. Explain how a constraint on total participation of *A* in *R* can be enforced using **not null** constraints in SQL.

Answer:
The foreign-key attribute in *R* corresponding to the primary key of *B* should be made **not null**. This ensures that no tuple of *A* which is not related to any entry in *B* under *R* can come in *R*. For example, say **a** is a tuple in *A* which has no corresponding entry in *R*. This means when *R* is combined with *A*, it would have a foreign-key attribute corresponding to *B* as **null**, which is not allowed.

6.11 In SQL, foreign key constraints can reference only the primary key attributes of the referenced relation or other attributes declared to be a superkey using the **unique** constraint. As a result, total participation constraints on a many-to-many relationship set (or on the "one" side of a one-to-many relationship set) cannot be enforced on the relations created from the relationship set, using primary key, foreign key, and not null constraints on the relations.

a. Explain why.

b. Explain how to enforce total participation constraints using complex check constraints or assertions (see Section 4.4.8). (Unfortunately, these features are not supported on any widely used database currently.)

Answer:

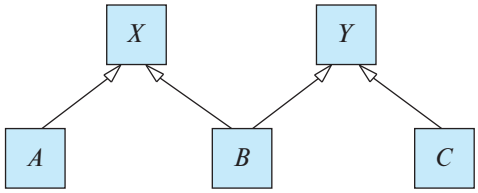
a. For the many-to-many case, the relationship set must be represented as a separate relation that cannot be combined with either participating entity. Now, there is no way in SQL to ensure that a primary-key value occurring in an entity $E1$ also occurs in a many-to-many relationship R, since the corresponding attribute in R is not unique; SQL foreign keys can only refer to the primary key or some other unique key.
Similarly, for the one-to-many case, there is no way to ensure that an attribute on the one side appears in the relation corresponding to the many side, for the same reason.

b. Let the relation R be many-to-one from entity A to entity B with a and b as their respective primary keys. We can put the following check constraints on the "one" side relation B:

constraint *total_part* **check** (b in (**select** b **from** A));
set constraints *total_part* **deferred**;

Note that the constraint should be set to deferred so that it is only checked at the end of the transaction; otherwise if we insert a b value in B before it is inserted in A, the constraint would be violated, and if we insert it in A before we insert it in B, a foreign-key violation would occur.

6.12 Consider the following lattice structure of generalization and specialization (attributes not shown).



For entity sets A, B, and C, explain how attributes are inherited from the higher-level entity sets X and Y. Discuss how to handle a case where an attribute of X has the same name as some attribute of Y.

Answer:
A inherits all the attributes of X, plus it may define its own attributes. Similarly, C inherits all the attributes of Y plus its own attributes. B inherits the attributes of both X and Y. If there is some attribute *name* which belongs to both X and Y, it may be referred to in B by the qualified name $X.name$ or $Y.name$.

6.13 An E-R diagram usually models the state of an enterprise at a point in time. Suppose we wish to track *temporal changes*, that is, changes to data over time. For example, Zhang may have been a student between September 2015 and

May 2019, while Shankar may have had instructor Einstein as advisor from May 2018 to December 2018, and again from June 2019 to January 2020. Similarly, attribute values of an entity or relationship, such as *title* and *credits* of *course*, *salary*, or even *name* of *instructor*, and *tot_cred* of *student*, can change over time.

One way to model temporal changes is as follows: We define a new data type called **valid_time**, which is a time interval, or a set of time intervals. We then associate a *valid_time* attribute with each entity and relationship, recording the time periods during which the entity or relationship is valid. The end time of an interval can be infinity; for example, if Shankar became a student in September 2018, and is still a student, we can represent the end time of the *valid_time* interval as infinity for the Shankar entity. Similarly, we model attributes that can change over time as a set of values, each with its own *valid_time*.

a. Draw an E-R diagram with the *student* and *instructor* entities, and the *advisor* relationship, with the above extensions to track temporal changes.

b. Convert the E-R diagram discussed above into a set of relations.

It should be clear that the set of relations generated is rather complex, leading to difficulties in tasks such as writing queries in SQL. An alternative approach, which is used more widely, is to ignore temporal changes when designing the E-R model (in particular, temporal changes to attribute values), and to modify the relations generated from the E-R model to track temporal changes.

Answer:

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a. The E-R diagram is shown in Figure 6.106.
The primary key attributes *student_id* and *instructor_id* are assumed to be immutable, that is, they are not allowed to change with time. All other attributes are assumed to potentially change with time.

Note that the diagram uses multivalued composite attributes such as *valid_times* or *name*, with subattributes such as *start_time* or *value*. The *value* attribute is a subattribute of several attributes such as *name, tot_cred* and *salary*, and refers to the name, total credits or salary during a particular interval of time.

b. The generated relations are as shown below. Each multivalued attribute has turned into a relation, with the relation name consisting of the original relation name concatenated with the name of the multivalued attribute. The relation corresponding to the entity has only the primary-key attribute, and this is needed to ensure uniqueness.

student(student_id)
student_valid_times(student_id, start_time, end_time)
student_name(student_id, value, start_time, end_time
student_dept_name(student_id, value, start_time, end_time
student_tot_cred(student_id, value, start_time, end_time
instructor(instructor_id)
instructor_valid_times(instructor_id, start_time, end_time)
instructor_name(instructor_id, value, start_time, end_time
instructor_dept_name(instructor_id, value, start_time, end_time
instructor_salary(instructor_id, value, start_time, end_time
advisor(student_id, instructor_id, start_time, end_time)

The primary keys shown are derived directly from the E-R diagram. If we add the additional constraint that time intervals cannot overlap (or even the weaker condition that one start time cannot have two end times), we can remove the *end_time* from all the above primary keys.

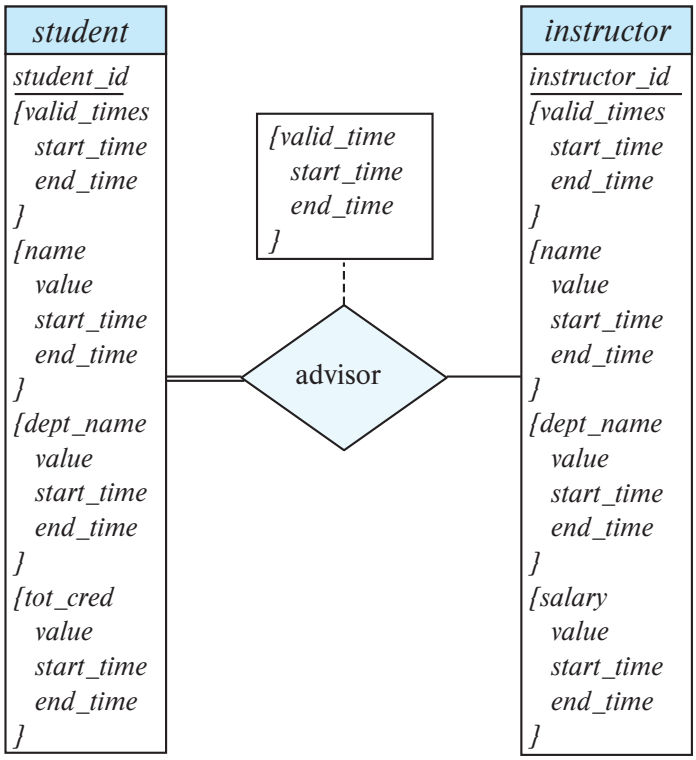

Figure 6.106 E-R diagram for Exercise 6.13