A Structured Approach To Teaching Cardinalities In The AIS Class

Guido L. Geerts, (E-mail: geerts@aisvillage.com), University of Delaware

Abstract

Cardinalities specify business rules as part of a conceptual schema. This paper presents a structured approach to teaching cardinalities in the accounting information systems (AIS) class. First, cardinalities are explained – why they are important, what they are and what notations exist to define them. Next, a three-step approach to teaching cardinalities is presented: syntactic, semantic and heuristic. Visual and syntactic representations help students understand the cardinality concept and cardinality notation. During the semantic phase, students learn to define business rules in terms of cardinalities. Heuristics help students recognize domain-specific stereotypical cardinality patterns. Such a generalization requires the existence of a semantic framework, and the REA model is used to define cardinality heuristics for enterprise systems. Finally, inter-relationship constraints, which represent participation dependencies across two or more relationships, are discussed.

Introduction

The data modeling approach to accounting information systems (AIS) has become increasingly popular among AIS educators (Hollander et al., 2000; Romney and Steinbart, 2003). Data models are used for the specification of conceptual schemas which represent a specific portion of reality. Conceptual schemas have a dual role (Taylor, 1990; Batini et al., 1992; Teorey, 1994; Jacobson et al., 1995; Eriksson and Penker, 2000). First, they provide a definition of the enterprise model; that is, the description of the phenomena to be captured in the information system such as the economic activities of a company. Second, they provide a starting point for the actual design of the information system. A data model provides a set of modeling constructs such as entity, relationship and cardinality to define conceptual schemas. Entities depict the basic things that need to be represented in the information system, and relationships depict associations among two or more entities. Cardinalities define participation constraints for relationships and have two specific roles: (1) they are used to primarily define business rules as part of the enterprise model specifications, and (2) they can be used as part of a top-down normalization process during the actual design of the information system (Nijssen and Halpin, 1989; Batini et al., 1992). The objective of this paper is to present a structured approach for teaching students how to use cardinalities to define business rules as part of the enterprise model.

What are cardinalities? Romney and Steinbart (2003) define cardinalities as follows: "Cardinalities indicate how many instances of one entity can be linked to one specific instance of another entity" (p.123). Stated differently, cardinalities express constraints on the participation of instances of an entity in a relationship. There are two different types of constraints and thus two different types of cardinalities: the minimum cardinality and the maximum cardinality. A minimum cardinality defines whether an instance has to participate in a relationship. If "yes," the participation is mandatory. If "no," the participation is optional. Therefore, the minimum cardinality defines a dependency. Put another way, the following question arises: can an instance exist without participating in the relationship? "Yes" means that participation is optional while "no" means that participation is mandatory. The maximum cardinality defines the number of times an instance can participate in a relationship. A constraint exists if an instance can participate only once in a relationship. No constraint exists if an instance can participate many times in a relationship. Figure 1 illustrates the definition of cardinalities using the Batini et al. (1992) notation. Both a minimum and a maximum cardinality are defined for each entity that participates in the relationship. Binary relationships, like the one in Figure 1, connect two entities and thus have four cardinalities defined. Instances of entity A do not have to participate in the relationship (MIN: "O"), but if they do, they can participate only once

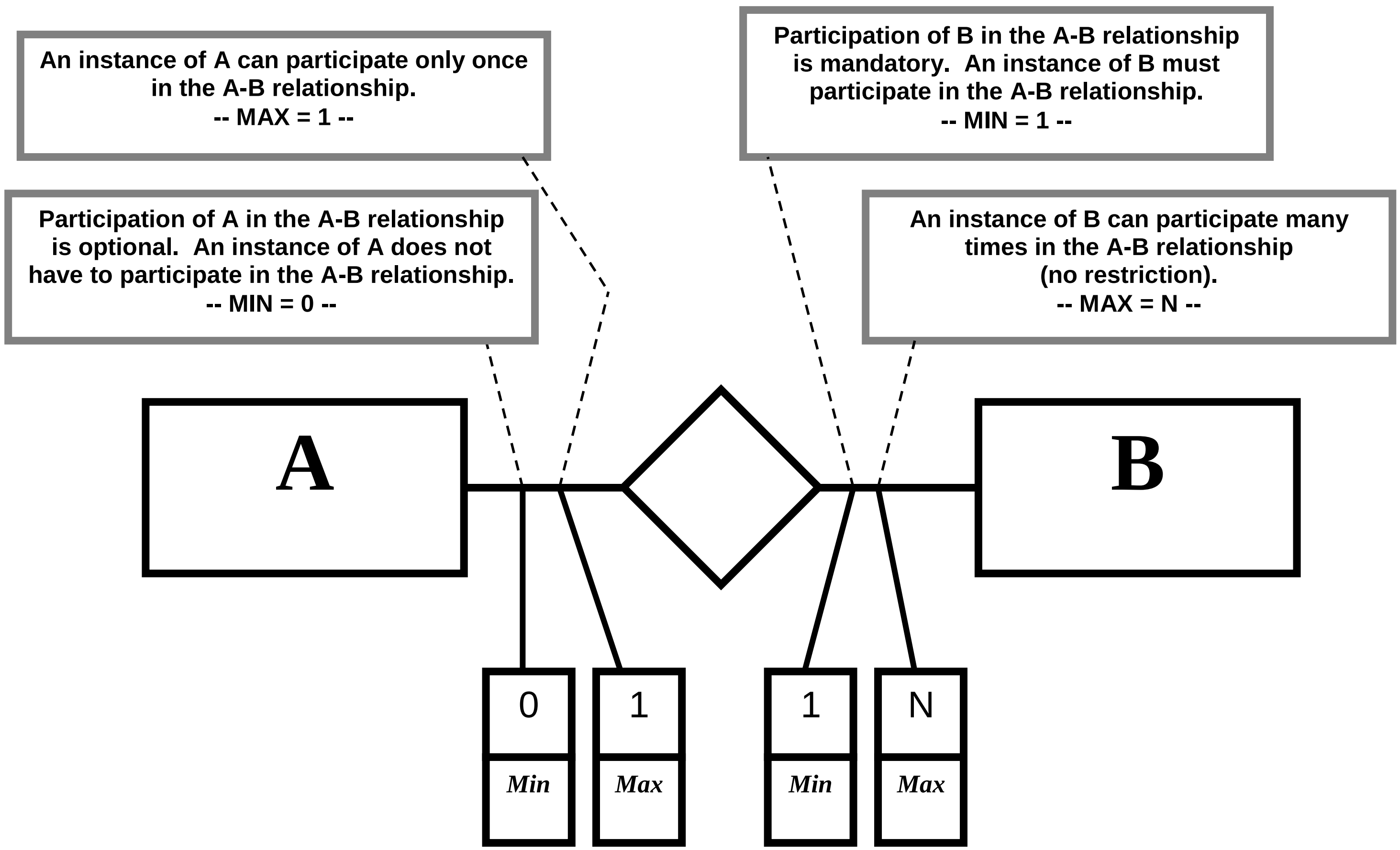

Figure 1 – Cardinalities: Notation

(MAX: "1"). Instances of entity B have to participate in the relationship (MIN: "1") and they can participate many times ("N").

A data modeling notation or syntax consists of a set of symbols and a set of rules that govern the way the symbols are combined and used. Different notations exist to express cardinalities. First, it is important to note that the symbols used to express cardinalities vary across notations. The notation used in this paper, the Batini et al. (1992) notation, is illustrated in Figure 1 and defines cardinalities with the following set of symbols: Min: {0,1}, Max: {1,N}. UML, the Unified Modeling Language (Booch et al., 1999), uses a "*" instead of an "N" for a no constraint maximum cardinality. Some other notations use graphical symbols such as the "crow's foot" symbol to define cardinalities (e.g., Martin and Odell, 1992). Second, rules determining where to graphically depict cardinalities in data models also differ across notations. For the example in Figure 1, the (0,1) cardinalities at the left side of the relationship express constraints on the participation of instances of the entity A in the relationship between A and B. However, other notations put the constraints that apply to the participation of an entity instance in a relationship at the opposite side of the relationship. A number of AIS textbooks have adopted the latter notation, including Hollander et al. (2000). UML also has adopted this practice.

Regardless of the data modeling notation used, the main reason for defining cardinalities as part of an enterprise model is to express business rules. Geerts et al. (2002) recognize three different phases in learning cardinalities: (1) Syntactic: What cardinalities are and what they stand for. (2) Semantic: How domain-specific business rules can be expressed in terms of cardinalities. (3) Heuristic: How to recognize and apply domain-specific stereotypical cardinality patterns. This paper presents a structured approach to teaching cardinalities in the AIS class that mirrors these three different phases and looks at more complex participation constraints existing between two or more relationships.

A Structured Approach to Teaching Cardinalities in the AIS Class

The structured approach to teaching cardinalities presented in this paper is based on the three phases recognized by Geerts et al. (2002): syntactic, semantic and heuristic. These three phases expose students to different aspects of cardinalities. The purpose of the syntactic phase is to familiarize students with the concept of cardinalities and with the selected notation. Questions to be addressed include "What are cardinalities?" and "What symbols can I use to define cardinalities and how should I use them?" There are two different steps in the syntactic phase: visual representation of cardinalities and syntactic definition of cardinalities. Visual representations help students to understand that cardinalities express constraints on the participation of instances in a relationship. The syntactic definitions spell out the meaning of each cardinality independent of their domain-specific meaning. During the semantic phase, students learn to translate domain-specific business rules into cardinality patterns. To do this, students must understand the business rule, e.g., "What do we mean by an open order or by installments?" In addition, students must be able to express the business rule in terms of cardinalities. Finally, the use of a domain-specific framework such as the Resource-Event-Agent (REA) model (McCarthy, 1982) allows for the specification of stereotypical cardinality patterns. These patterns or heuristics provide students with rules of thumb which they can use when defining enterprise models. Each of the three phases – syntactic, semantic and heuristic – is explored in more detail below.

Syntactic definition of cardinalities

The objective of the syntactic phase is for students to explore the following two issues: what cardinalities are and how the data modeling notation is used to express them. Using visual representations is an effective starting tool. An example is given in Figure 2. A key characteristic of a visual representation is that instances are explicitly represented. An important assumption is that the reality modeled exists only of those instances represented in that specific model. The visual representation helps students understand the meaning of cardinalities as constraints on the participation of instances of an entity in a relationship. The diagram in Figure 2 graphically shows that a minimum cardinality with value "0" implies that the participation of instances of an entity in the relationship is optional. One of the employees in Figure 2 does not participate in the "assigned-to" relationship. The diagram in Figure 2 also graphically shows that a minimum cardinality with value "1" implies that the participation of instances of an entity

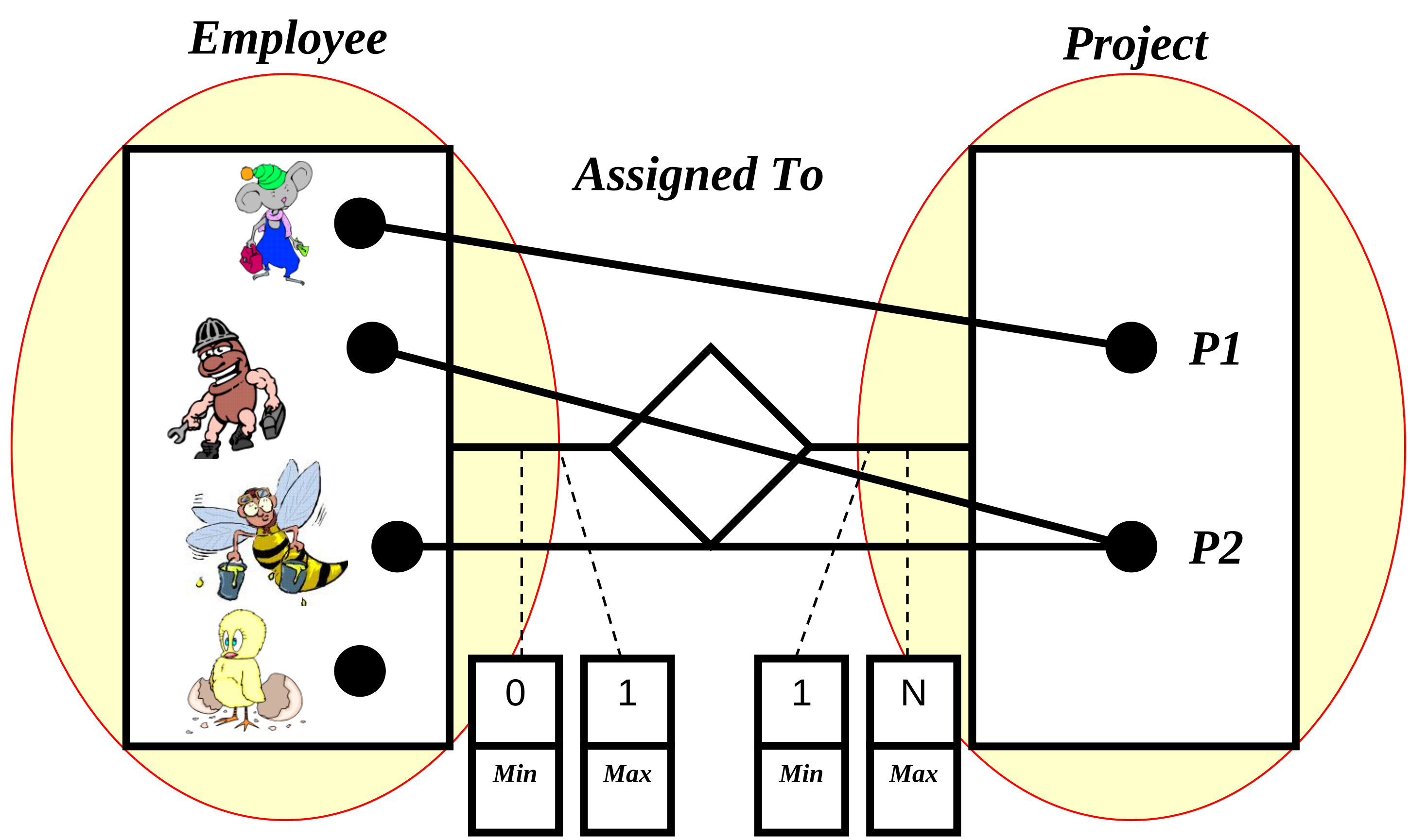

Figure 2 – Visual Representation of Cardinalities

in the relationship is mandatory. Each instance of the project entity participates in the "assigned-to" relationship. Since domain-knowledge is of no importance both non-accounting and accounting examples are useful.

The example in Figure 3 defines cardinalities as rules that apply to all current and future instances of the entities; it no longer represents instances. The distinguishing feature of syntactic definitions of cardinalities is that the participation constraints are explicitly defined and that no domain-specific knowledge is required. Syntactic definitions explicitly tell students two things: whether or not an entity instance must participate in the relationship and the number of times an instance can participate in the relationship. For example, the first rule (R1) "Not all vendors participate in the vendor-item relationship**"** states that the participation of vendor instances in the relationship is optional (MIN = "0"). The last rule (R4) "Most vendors participate many times in the vendor-item relationship" states that an instance of vendor can participate many times in the relationship; i.e., the maximum cardinality is "N" since no constraint exists. Since domain-knowledge is of no importance, both non-accounting and accounting examples are useful.

Semantic definition of cardinalities

The objective of the semantic phase is for students to learn how to use cardinalities to define business rules as part of an enterprise model. Thus, semantic definitions of cardinalities no longer describe the participation rules explicitly. Figure 4 illustrates a non-accounting example of a semantic representation for which no rules are specified. The definition of cardinalities for this problem requires a good understanding of the parent and children concepts and how they relate to each other. Parents are individuals that have at least one child (1,N), and children are individuals that have two parents (1,N). The cardinalities are based on the meaning, i.e., the semantics, of the entities involved: What is a parent? What is a child?

Figure 5 provides an illustration of an accounting example that mixes semantic and syntactic definitions. The participation rules for order are not explicitly defined while the participation rules for delivery are. For the order entity, the narrative describes two business rules (R1 and R2) that recognize the existence of open orders and partial deliveries. First, students need in-depth knowledge of the business concepts described: what open orders are and what partial deliveries are. Second, they must be able to translate these business concepts into cardinalities. Both steps are explored for open orders and partial deliveries below.

Open orders

1. What are open orders? An open order is an order that has not yet been completely filled.
2. How does that translate into cardinalities? Orders might exist for which no delivery has as yet taken place and participation of order in the relationship between order and delivery is thus optional. The minimum cardinality is "0."

Partial deliveries

1. What are partial deliveries? When an order is filled in multiple steps, each step is called a partial delivery.
2. How does that translate into cardinalities? An order instance might need more than one delivery and thus might participate many times in the order-delivery relationship. The maximum cardinality is "N."

The translation of business rules and business concepts into cardinalities is the main objective of teaching cardinalities in the AIS class. Other examples of business concepts that can be expressed by cardinalities as part of an enterprise model are installments, down payments and unearned revenue.

R1: Not all vendors participate in the vendor-item relationship.

R2: For some items we know more than one vendor.

R3: We know at least one vendor per item.

R4: Most vendors participate many times in the vendor-item relationship.

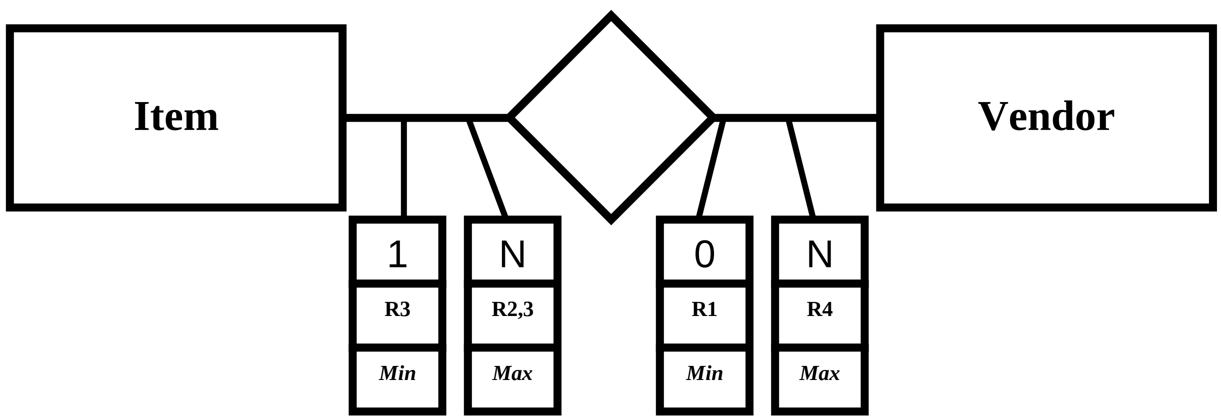

Figure 3 – Syntactic Definition of Cardinalities

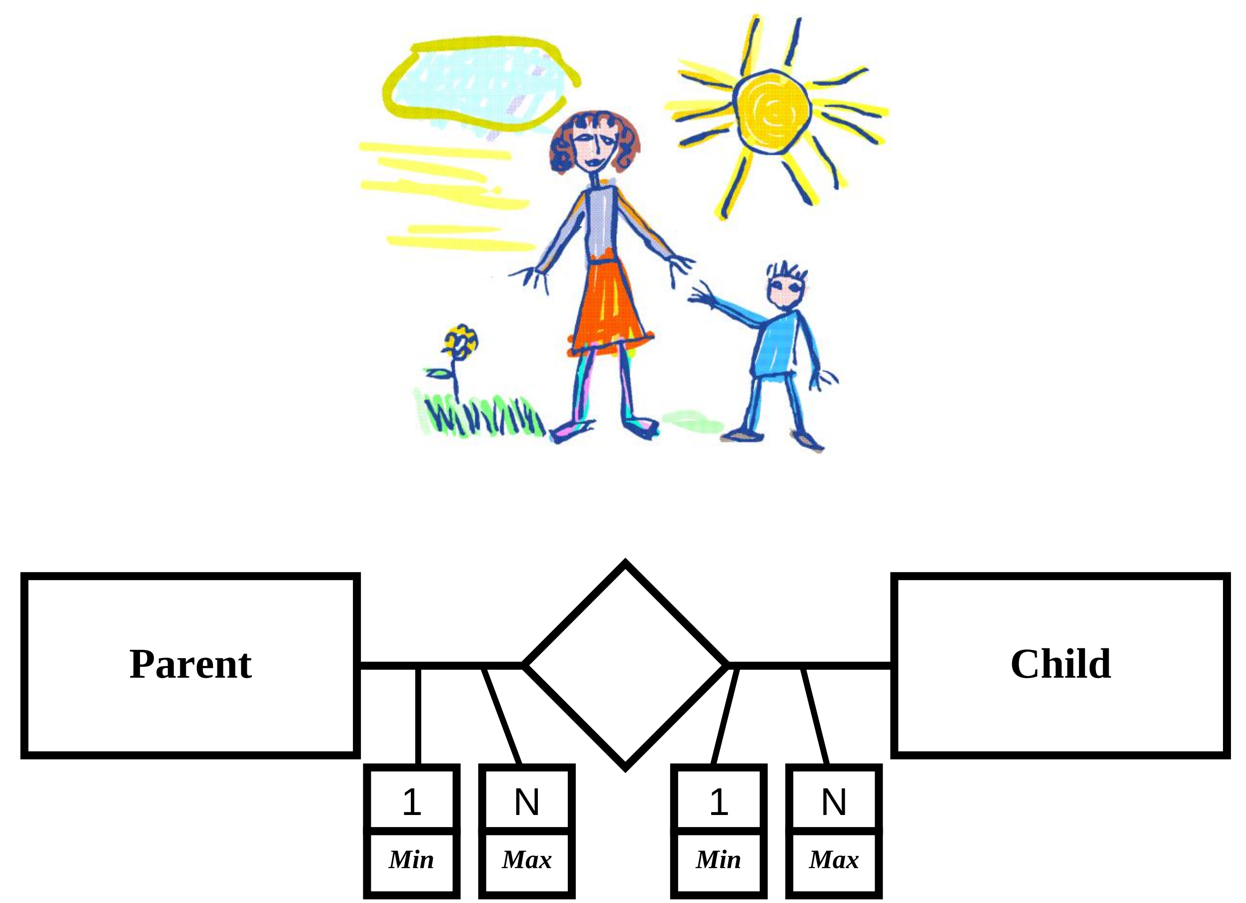

Figure 4 – Semantic Definition of Cardinalities: Non-Accounting Example

R1: We currently have more than 100 open orders.

R2: We accept partial deliveries from vendors.

R3: There is exactly one order for each delivery.

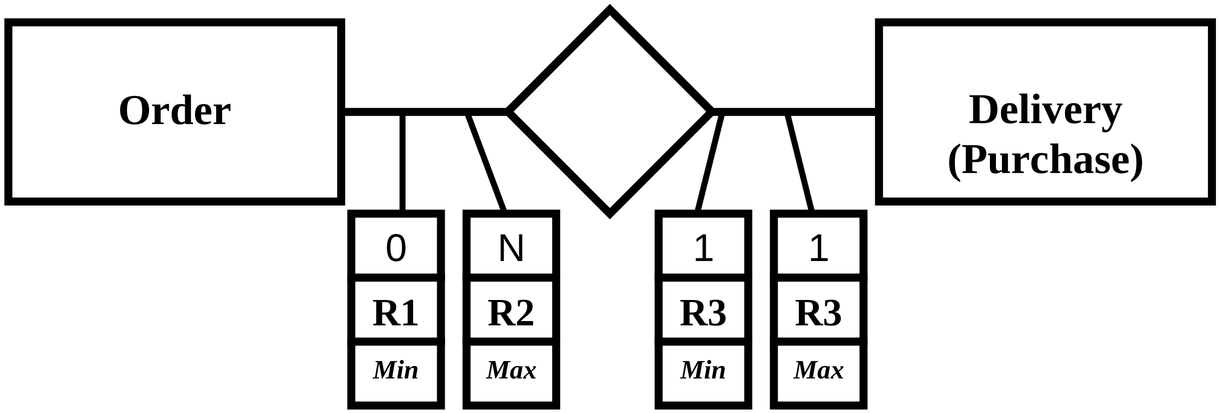

Figure 5 – Semantic Definition of Cardinalities: Accounting Example

Cardinality heuristics

The objective of the heuristic phase is for students to learn some rules of thumb, i.e., stereotypical cardinality patterns for domain-specific relationships. The definition of such heuristics requires the existence of a domain-specific semantic framework. The REA model shown in Figure 6 is a semantic framework for accounting and defines a business process by linking give and take economic events (duality) and by defining resources and agents (internal and external) for each economic event. Stereotypical cardinality patterns can be defined for some of the REA relationships. The upper part of Figure 7 shows the REA "participation" relationship between an economic event and an economic agent, while the lower part shows the relationship between sale (economic event) and shipping clerk (internal agent) as a specific instantiation of the participation relationship. Heuristics define patterns that apply to most but not necessarily to all instantiations. Both the minimum and maximum cardinalities at the economic event side are typically one. Participation is mandatory (MIN = "1") because an event must have an agent who is accountable for it, but only one agent is typically accountable for it (MAX = "1"). These heuristics hold for the sale – shipping clerk instantiation in the lower half of Figure 7. Typically, you want a shipping clerk to be accountable for each sale but you want only one shipping clerk to be accountable. Further, it is common to record agent information before they participate in the REA "participation" relationship – potential customers, vendors you would like to do business with, employees whose information is recorded in the information system at the time they are hired, etc. (MIN = "0"). Also, agents typically participate many times in the REA "participation" relationship; for example, a shipping clerk can be accountable for more than one sale (MAX = "N"). Heuristics provide students with domain-specific expertise, namely, generalizations of commonly defined business rules.

Inter-Relationship Constraints

The structured approach to learning cardinalities presented in the previous section exposes students gradually to different aspects of cardinalities: (1) what cardinalities are and how to define them, (2) how to use them to express business rules as part of an enterprise model, and (3) how to recognize and apply stereotypical cardinality patterns for enterprise models. After completing these three phases, instructors might want to expose students to inter-relationship constraints. These constraints represent participation dependencies across two or more relationships and are useful for the modeling of a wide variety of business rules. In exploring the use of inter-relationship constraints for the specification of business rules as part of an enterprise model in this section, it is first helpful to look at two common examples of inter-relationship constraints: time dependencies and exclusive roles. Then, the data modeling notation with equality, subset, exclusion and total union inter-relationship constraints can be explored.

Time dependencies and exclusive roles

Cardinalities express restrictions on the participation of instances of an entity in a relationship. Cardinalities are intra-relationship constraints since they apply to one relationship. When an entity participates in more than one relationship, interdependencies might exist between the participation of the entity instances in the different relationships, such as "If an instance of an entity participates in one relationship, it cannot participate in another relationship." Common examples of such inter-relationship constraints are time dependencies and exclusive roles.

The diagram in Figure 8 portrays a time dependency (TD). The minimum cardinality of "0" for the participation of item instances in the item-order and item-warehouse relationships expresses the rule that a new item can be considered before it is ordered and before it is stored in a warehouse. However, not all items that are ordered are stored in a warehouse yet; that is, items are ordered first and stored in a warehouse later. The bottom part of Figure 8 further illustrates this time dependency as a subset relationship at the instance level – all item instances that are stored in a warehouse {i1, i2 and i3} have been ordered, but some items that have been ordered {i4, i5} are not stored in a warehouse.

Figure 9 illustrates an example where two relationships are defined between the employee and project entities. These relationships represent the different roles of an employee with regard to a project: "manager" and

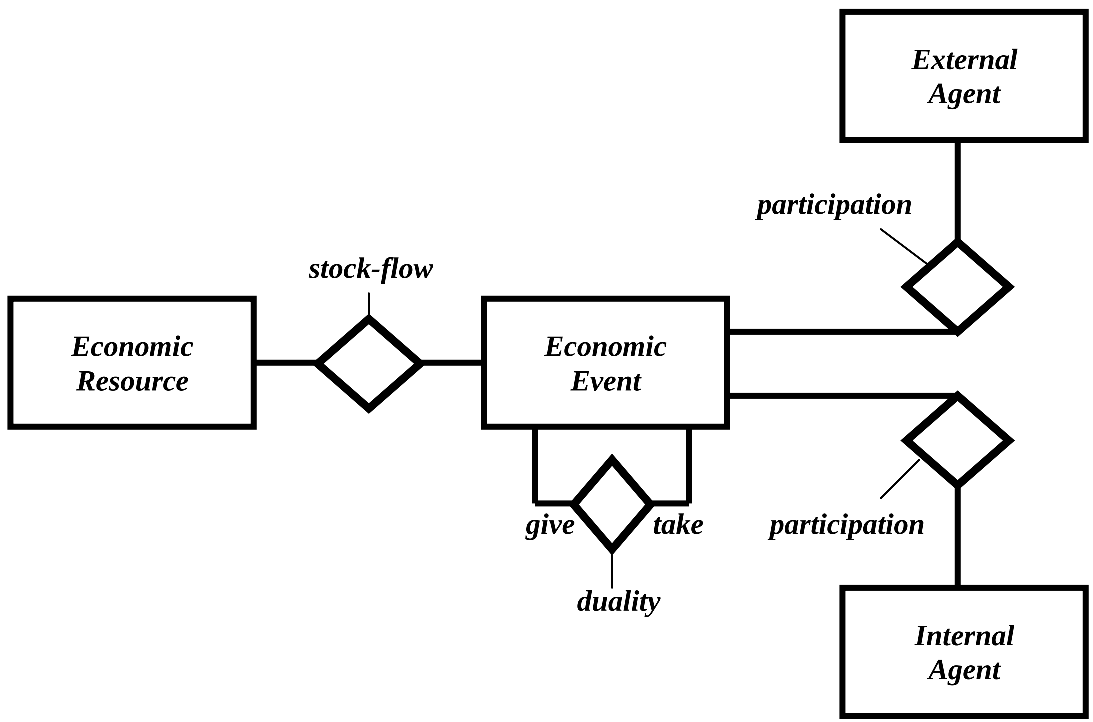

Figure 6 – REA Model (adapted from McCarthy 1982)

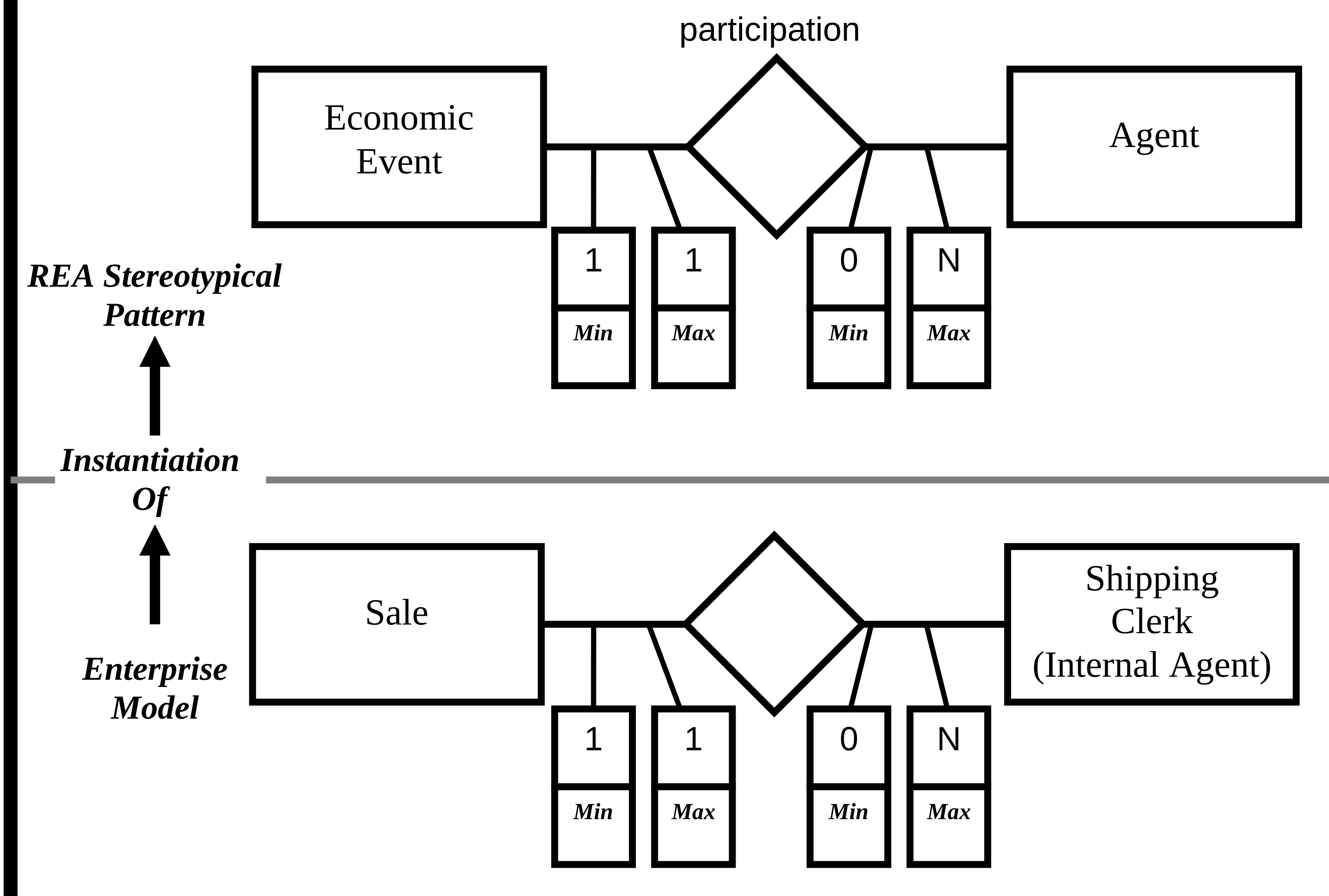

Figure 7 – Cardinality Heuristics

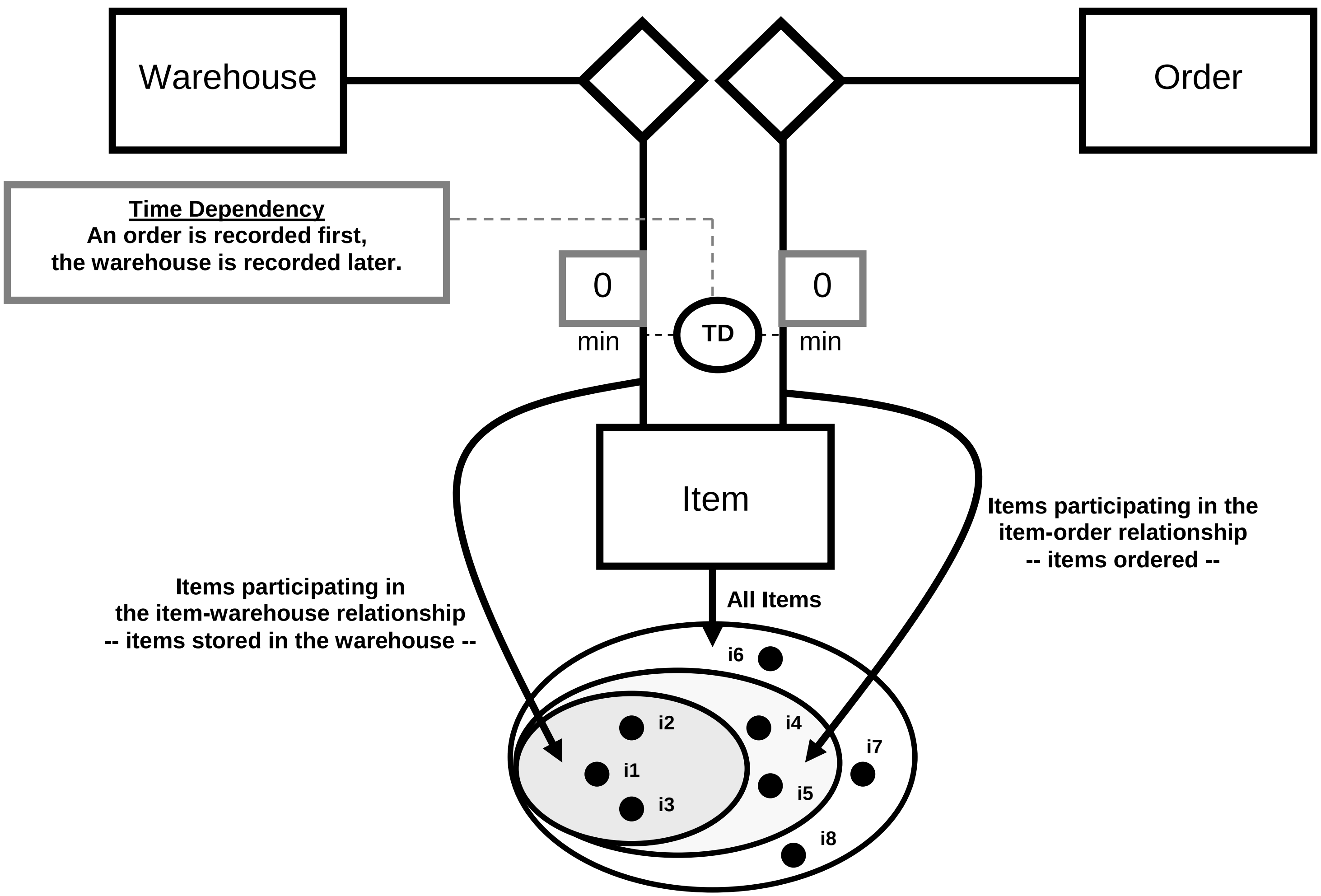

Figure 8 – Time Dependencies

"assistant." Participation interdependencies often exist for such a multiple-relationships construction. For example, the manager and assistant roles in Figure 9 could be defined as being exclusive. What is the business rule that such exclusive roles express? An employee who participates in the manager relationship cannot participate in the assistant relationship and vice versa. Figure 9 further illustrates the concept of exclusive roles at the instance level – none of the managers {e1,e2} are assistants and none of the assistants {e3,e4} are managers.

Explicitly defined inter-relationship constraints

Cardinalities represent intra-relationship constraints; i.e. constraints on the participation of instances in one specific relationship. Inter-relationship constraints define rules for the participation of an instance in more than one relationship. Inter-relationship constraints were first introduced in Nijssen and Halpin (1989) and then used as extensions to other data models (Geerts 1991, Teorey 1994). This paper uses the extended E-R notation as presented in Geerts (1991) to define four inter-relationship constraints: equality, subset, exclusion and total union.

All inter-relationship constraints have the following three common characteristics:

1. Inter-relationship constraints always relate to the participation of instances of the same entity in different relationships.
2. Participation of entities in a relationship that is subjected to an inter-relationship constraint is optional.
3. The number of times an entity occurs in a relationship doesn't matter; in other words, the value of the maximum cardinality is of no importance.

Figure 10 illustrates the meaning of each of the four inter-relationship constraints: equality, subset, exclusion and total union.

Equality (E). The diagram in the north-west corner of Figure 10 illustrates an equality constraint. Participation of project in the manager and assistant relationships is optional (MIN = "0"). However, if a project instance participates in one of the two relationships it must also participate in the other one. The equality constraint defines the following business rule: "A project with a manager must also have an assistant, and a project with an assistant must also have a manager."

Subset (S). The diagram in the north-east corner of Figure 10 illustrates a subset constraint. Participation of project in the manager and assistant relationships is optional (MIN = "0"). The subset relationship states that if a project has an assistant, then the same project must also have a manager. However, a project can have a manager and not an assistant. The time dependency in Figure 8 can be explicitly defined by a subset constraint.

eXclusion (X). The diagram in the south-west corner of Figure 10 illustrates an exclusion constraint. Participation of employee in the manager and assistant relationships is optional (MIN = "0"). The exclusion constraint states that an instance that participates in one relationship cannot participate in the other relationship and vice versa. The "X" exclusion constraint explicitly represents the exclusive roles depicted in Figure 9: "An employee who is assigned as a manager to a project cannot be assigned as an assistant to a project and vice versa."

Total union (T). The diagram in the south-east corner of Figure 10 illustrates a total union constraint. Participation of employee in the manager and assistant relationships is optional (MIN = "0"). The total union constraint states that each of the employee instances must participate in at least one of the connected relationships and defines the following business rule: "Each employee must be assigned to a project as a manager, as an assistant or as both."

Conclusions

This paper presents a structured approach to teaching cardinalities, consisting of three phases. Each phase exposes students to different aspects of cardinalities. (1) Syntactic: What cardinalities are and how to define them. (2) Semantic: How to express business rules with cardinalities. (3) Heuristic: How to recognize and apply domain-specific stereotypical cardinality patterns. The paper also discusses inter-relationship constraints. While

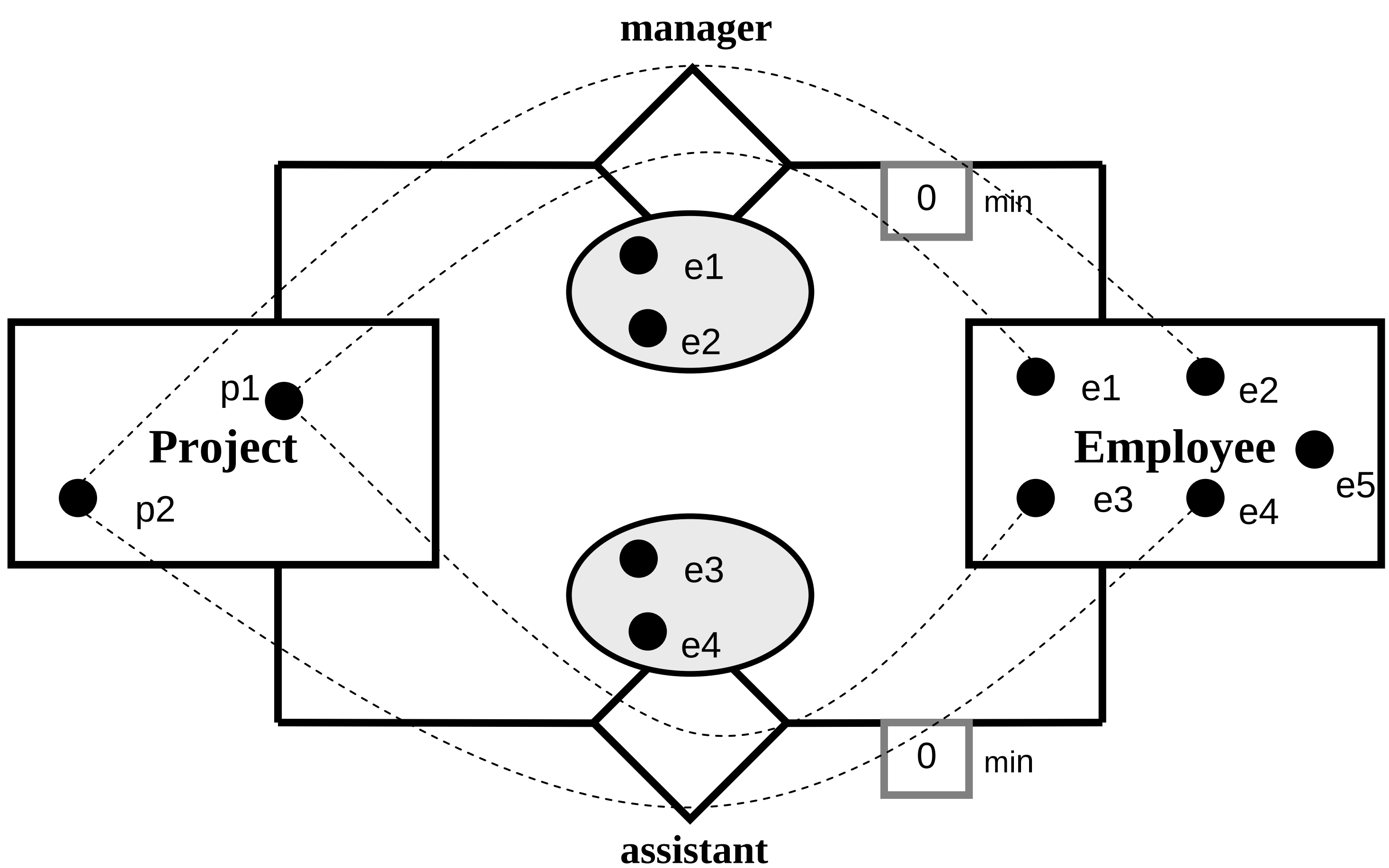

Figure 9 – Exclusive Roles

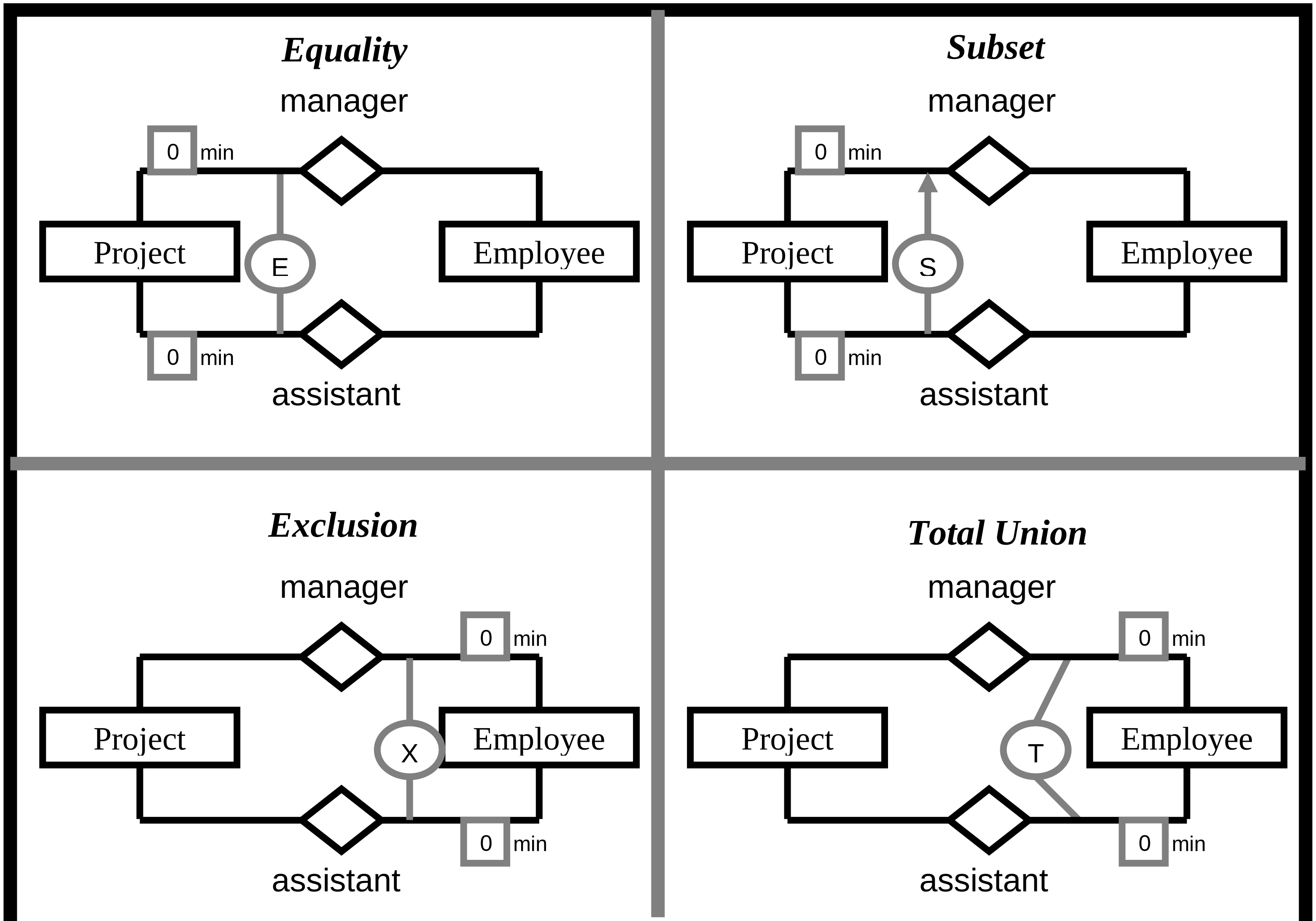

Figure 10 – Inter-Relationship Constraints

cardinalities restrict the participation of entities in one specific relationship, inter-relationship constraints express participation restrictions across relationships. Four different inter-relationship constraints were discussed - equality, subset, exclusion and total union - and then illustrated to show how they can be used to model business rules.

Instructors interested in using the structured approach to teaching cardinalities discussed in this paper can make use of "Stevie" (Geerts et al., 2002), an interactive Internet tool for learning cardinalities, for out-of-class assignments. Stevie has an assignment for each of the three different phases in the structured approach. Students can login as "syntactic, semantic and heuristic" (usernames) and the password for all three assignments is "public." The syntactic assignment includes a number of visual representations. Each of the assignments has a number of problems for which the student can submit an answer to the tool and get some interactive feedback. To access Stevie, go to www.aisvillage.com/stevie.

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