The Entity Relationship Model and Database Design

CPS352: Database Systems

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Agenda

- Check-in
- The Entity Relationship Model
- Group Exercise
- Database Design Principles
  - Functional Dependencies

Check-in

The Entity Relationship Model

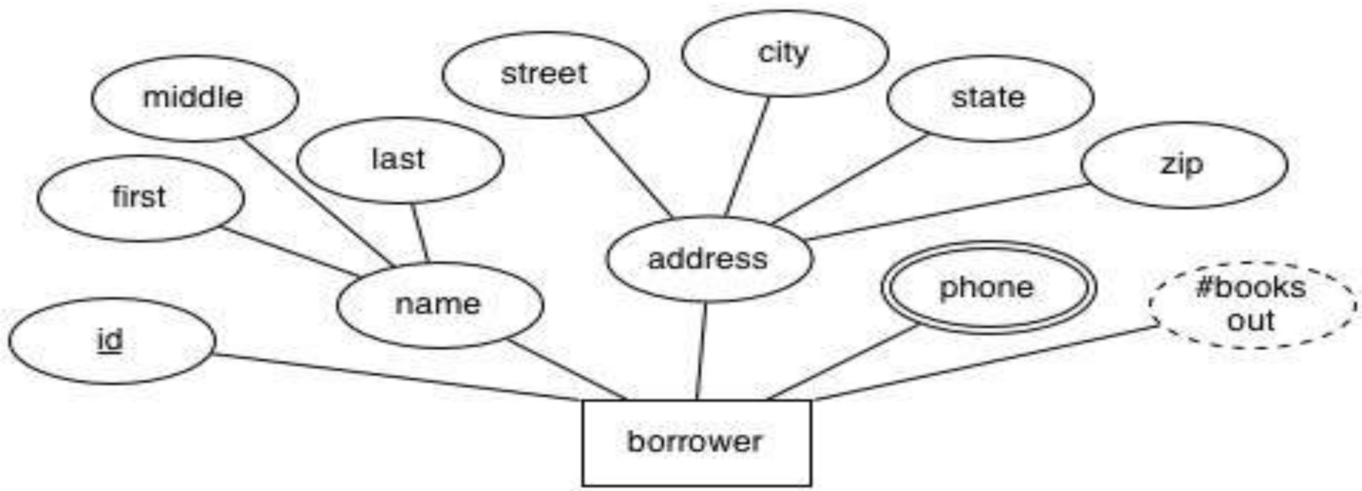
Background

- Entity relationship model as a conceptual database design tool
  - Not a DBMS implementation
    - No “entity relationship databases” available
- Entity relationship (E-R) diagrams help us think about the structure of a data model
  - Can be translated into relational schemas
  - Which then can be implemented in a DBMS
  - Analogous to use case or class diagrams in OO design

Entity Concepts

- Entity – an object being represented (along with its details)
- Entity set – the set of all objects of a given kind
- Attribute – individual fact about an entity
  - Often simple (atomic) and single-valued
  - Can be composite
  - Sometimes multi-valued
  - Can be derived from other attributes
    - Not necessarily stored with the entity, but calculated when needed
- Domain – set of possible values for an attribute
- Keys – set of attributes that uniquely identifies an entity
  - Superkeys, candidate keys, and primary key

Entities in E-R Diagrams



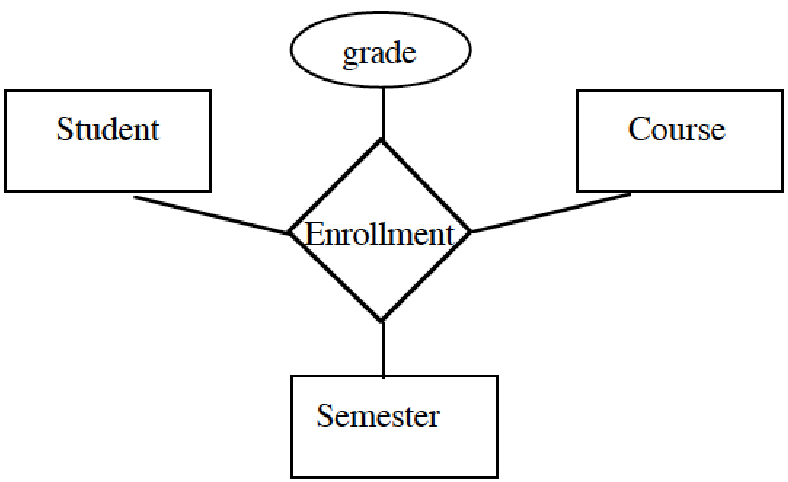
- Entity set represented by rectangular box containing name of entity
- Attributes represented by ellipses containing attribute names
  - Primary key attribute(s) underlined
  - Composite attributes displayed with a hierarchical structure
  - Multivalued attributes enclosed in double ellipses
  - Derived attributes enclosed in a dashed ellipse
- Attributes connected by lines to entity set

Relationship Concepts

- Relationship – the connection between two or more entities
  - A relationship with more than two entities can always be converted to a new entity plus relationships between the new and original entities
  - A relationship can be between an entity and itself
- Relationship set – set of all relationships of a given type
  - A subset of the Cartesian product of the entity sets
  - Degree of a relationship set is how many entities are involved in it (i.e. binary, ternary, quadranary, etc.)
- Descriptive attribute – a property of a relationship that does not apply to its associated entities
  - When a relationship of more than two entities is converted into a new entity, the original relationship's descriptive attributes become the new entity's attributes

Relationships in E-R Diagrams

- Relationship sets represented by diamonds
  - Connected with associated entities by solid lines (potentially doubled or decorated with arrows)
  - Descriptive attributes depicted the same as entity attributes
- Converting a ternary+ relationship to a new entity



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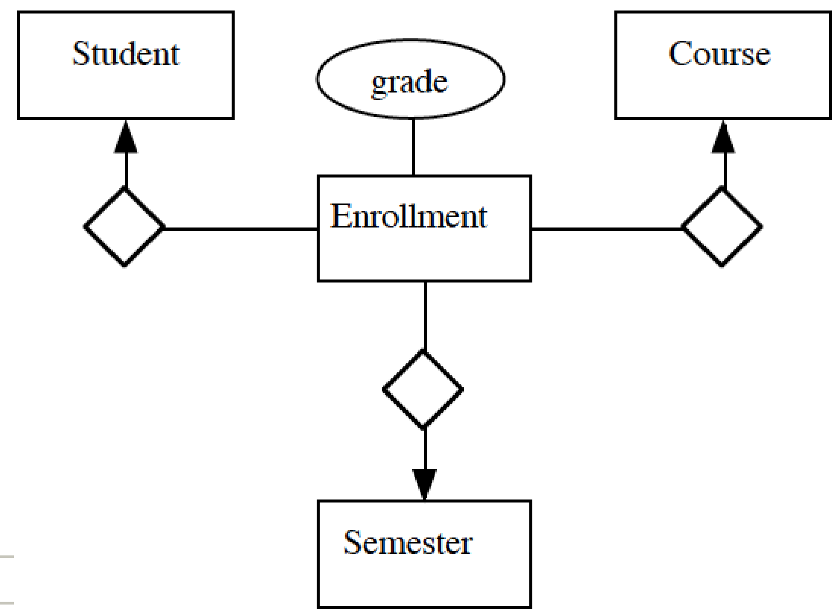


Mapping Constraints

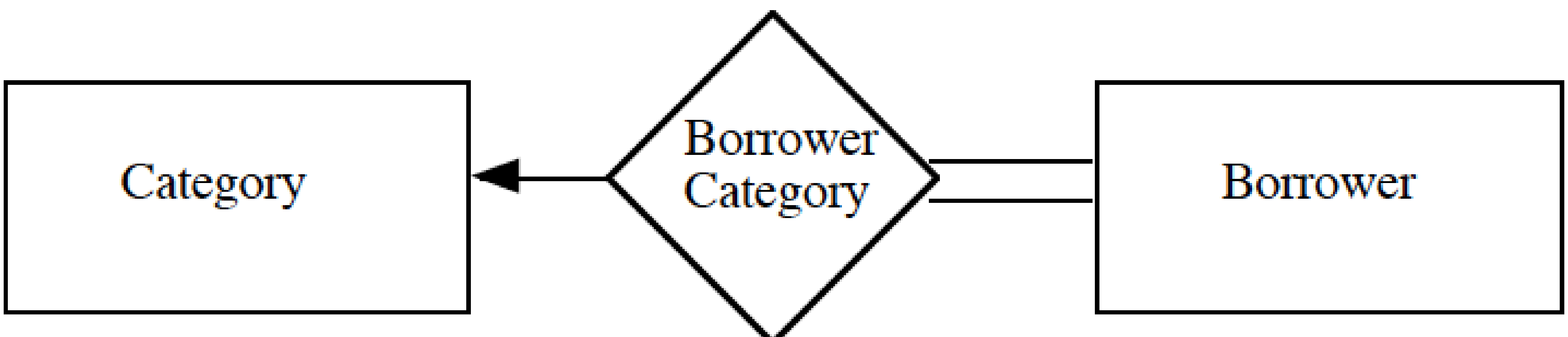
- Restrictions as to what kind of subsets are possible in a relationship set
- Mapping cardinalities – how many entities in each entity set can participate in the relationship
- Participation constraints – when an entity in one entity set *must* participate in a relationship
- Existence dependencies – when an entity in one entity set of a relationship is dependent on the existence of an entity in the other entity set
- Primary keys for relationship sets

Mapping Cardinalities

- One to one
  - Any member of either entity set involved can participate in at most one instance of the relationship set
  - Often represented by arrow heads pointing to both entities arrow in E-R diagrams
- One to many / Many to one
  - Basically the same concept (just in opposite directions)
  - Entities in the “one” entity set can participate in multiple relationships
  - Entities in the “many” entity set can participate in at most one
  - Often represented by an arrow head pointing to the “one” in E-R diagrams
- Many to many
  - Entities in either entity set can participate in multiple relationships
  - Often represented by a solid line to all entities in the relationship (no arrow heads)

Participation Constraints

- Total participation constraint
  - When the underlying of a relationship dictates that every entity in on entity set *must* participate in an instance of the relationship
- Represented by a double line between the relationship and the entity that must participate
- Example: every borrower must have a category

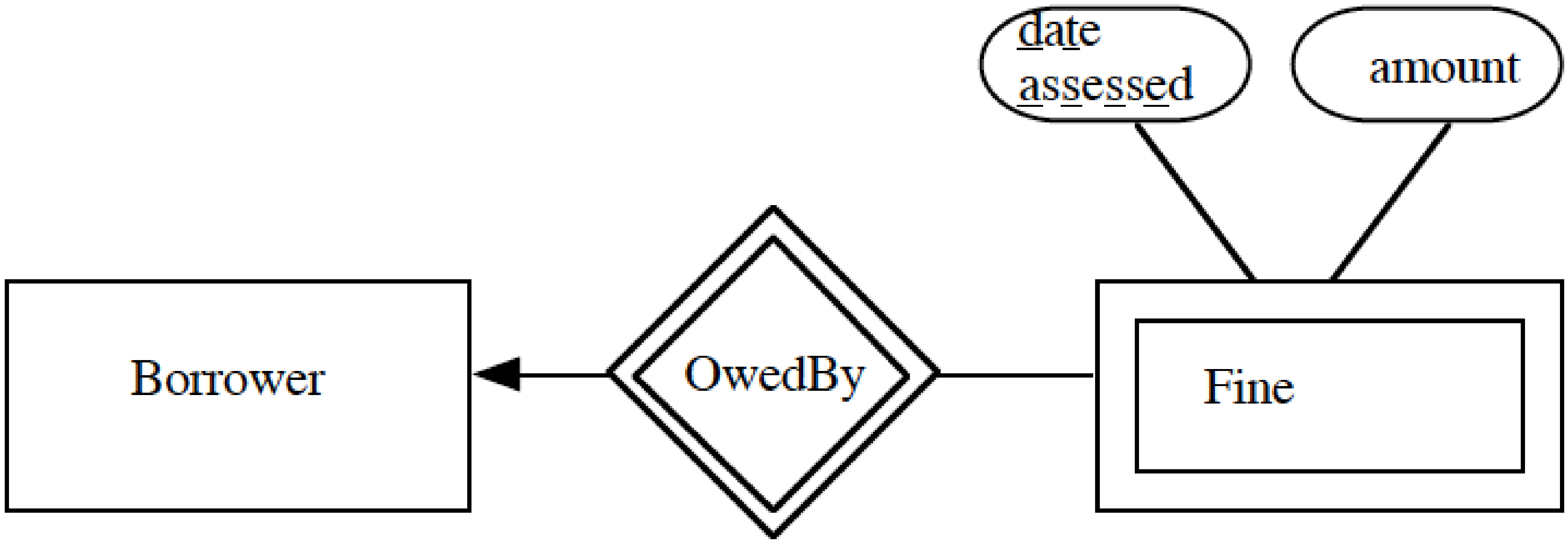


Existence Dependencies

- Weak entity set – an entity set in which each entity is dependent on the existence of an entity from another entity set
  - Has a *partial key* or *discriminator* which must be combined with attributes from the strong entity to uniquely identify it (no superkey)
  - If the *dominant* strong entity is deleted, the *subordinate* weak entity ceases to exist
- Example: Fines owed by borrowers

Weak Entities in E-R Diagrams

- Weak entity set represented by a double box
- Existence dependency relationship represented by a double diamond
- Partial key attributes underlined using a dashed line



Primary Keys for Relationship Sets

Mapping Cardinality	Key
Many to many	Union of key attributes in all involved entities
One to many Many to one	Primary key of the “many” entity
One to one	Primary key of either of the entities

Converting to the Relational Model

- Any database scheme consisting of entities and relationships can be represented by a series of tables
  - One for each entity set
  - One for each relationship set
    - Except when the relationship can be “folded” into an entity

Converting Entities to Tables

- Strong entity set
  - One row for each entity
  - One column for each attribute
- Weak entity set
  - One row for each entity
  - One column for each attribute
  - Add column(s) for the primary key of the strong entity on which the weak entity depends

Converting Relationships to Tables

- Relationship set
  - One row for each relationship
  - One column for each descriptive attribute
  - Column(s) for primary key attributes of each participating entity set
- “Folding” in one to one and one to many relationships
  - Into the many entity by including the foreign key of the “one” entity and any attributes
  - These will be null for an entity that is not in any relationship

Generalized and Specialized Entities

- An entity set may contain multiple groups of similar entities with common and distinct attributes
  - Example: different kinds of borrowers for students, faculty/staff, and community members
- Converting generalized/specialized entities to tables
  - One big table
  - One table per group
  - One generalized table with common attributes and one specialized table per group

Group Exercise

Complete Practice Exercise 7.1
On page 315 of *Database System Concepts*

Database Design

Introduction

- Terminology review
  - Relation scheme – set of attributes for some relation (R, R_1, R_2)
  - Relation – the actual data stored in some relation scheme (r, r_1, r_2)
  - Tuple – a single actual row in the relation (t, t_1, t_2)
- Changes to the library database schema
  - We make the following updates for this discussion
    - Add the following attributes to the book relation
      - copy_number – a library can have multiple copies of a book
      - accession_number – unique number (ID) assigned to a copy of a book when the library acquires it
  - New book and checked_out relation scheme
    - Book(<u>catalog_number</u>, <u>copy_number</u>, accession_number, title, author)
    - Checked_out(<u>borrower_id</u>, <u>catalog_number</u>, <u>copy_number</u>, date_due)

Database Design Issues

- Designing a database is a balancing act
- One the one extreme, you can have a *universal relation* (in which all attributes reside within a single relation scheme)
  - Everything

```
    borrower_id, last_name, first_name,  // from borrower
    call_number, copy_number,
    accession_number, title, author      // from book
    date_due                             // from checked_out
)
```

- Leads to numerous anomalies with changing data in the database

Decomposition

- *Decomposition* is the process of breaking up an original scheme into two or more schemes
  - Each attribute of the original scheme appears in at least one of the new schemes
- But this can be taken too far
  - Borrower(borrower_id, last_name, first_name)
  - Book(call_number, copy_number, accession_number, title, author)
  - Checked_out(date_due)
- Leads to *lossy-join* problems

Lossless-Join

- Part of the middle ground in the balancing act
  - Allows decomposition of the Everything relation
  - Preserves connections between the tuples of the participating relations
  - So that the natural join of the new relations = the original relation
- Formal definition
  - For some relation scheme R decomposed into two or more schemes (R_1, R_2, … R_n)
  - Where $R = R_1 \cup R_2 \cup \ldots \cup R_n$
  - A *lossless-join decomposition* means that for every legal instance r of R decomposed into r_1, r_2, … r_n of R_1, R_2, and R_n
  - $r = r_1$ |X| r_2 |X| … |X| r_n

Database Design Goal

- Decide whether a particular relation R is in "good" form.
- In the case that a relation R is not in "good" form, decompose it into a set of relations $\{R_1, R_2, ..., R_n\}$ such that
  - each relation is in good form
  - the decomposition is a lossless-join decomposition
- Our theory is based on:
  - functional dependencies
  - multivalued dependencies

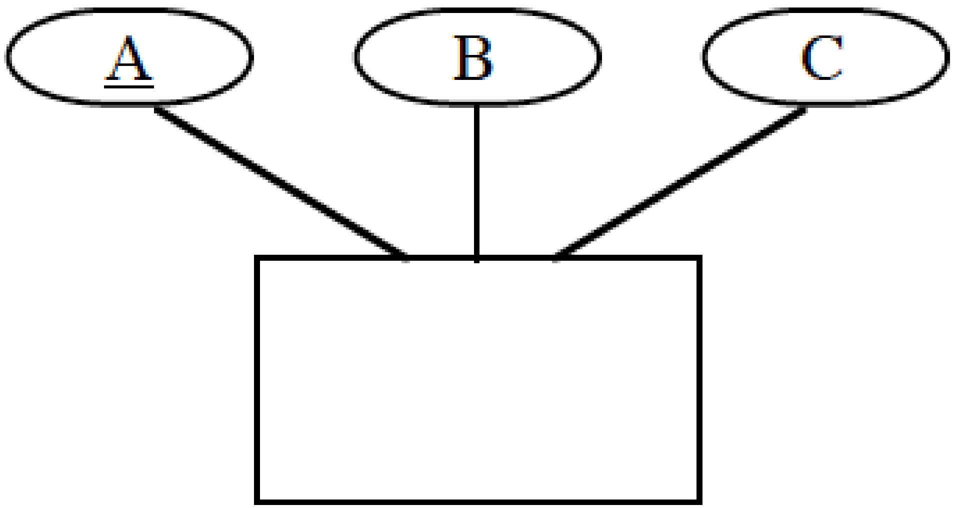
Functional Dependency (FD)

- When the value of a certain set of attributes uniquely determines the value for another set of attributes
  - Generalization of the notion of a key
  - A way to find "good" relations
  - $A \rightarrow B$ (read: A determines B)
- Formal definition
  - For some relation scheme R and attribute sets A ($A \subseteq R$) and B ($B \subseteq R$)
  - $A \rightarrow B$ if for any legal relation on R
    - If there are two tuples t_1 and t_2 such that $t_1(A) = t_2(A)$
    - It must be the case that $t_2(A) = t_2(B)$

Finding Functional Dependencies

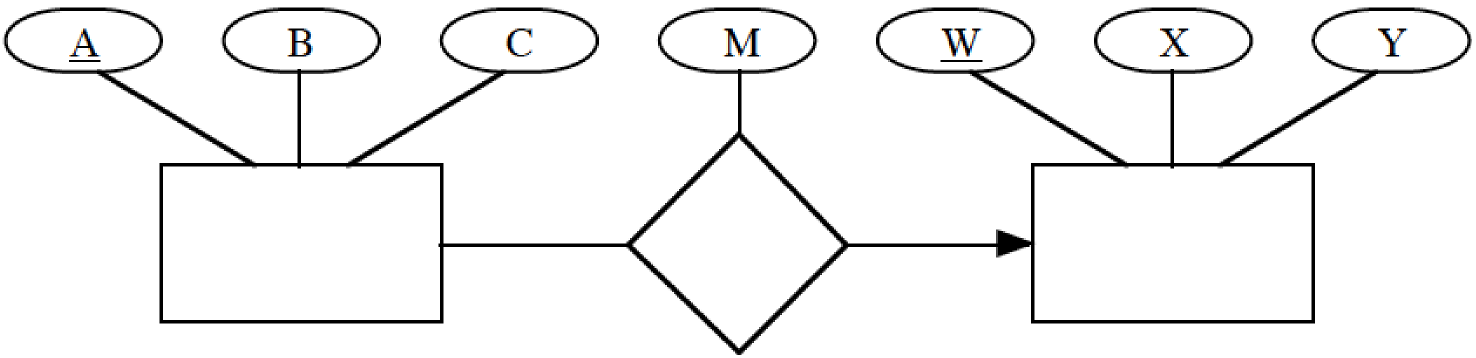
- From keys of an entity
- From relationships between entities
- Implied functional dependencies

FDs from Entity Keys



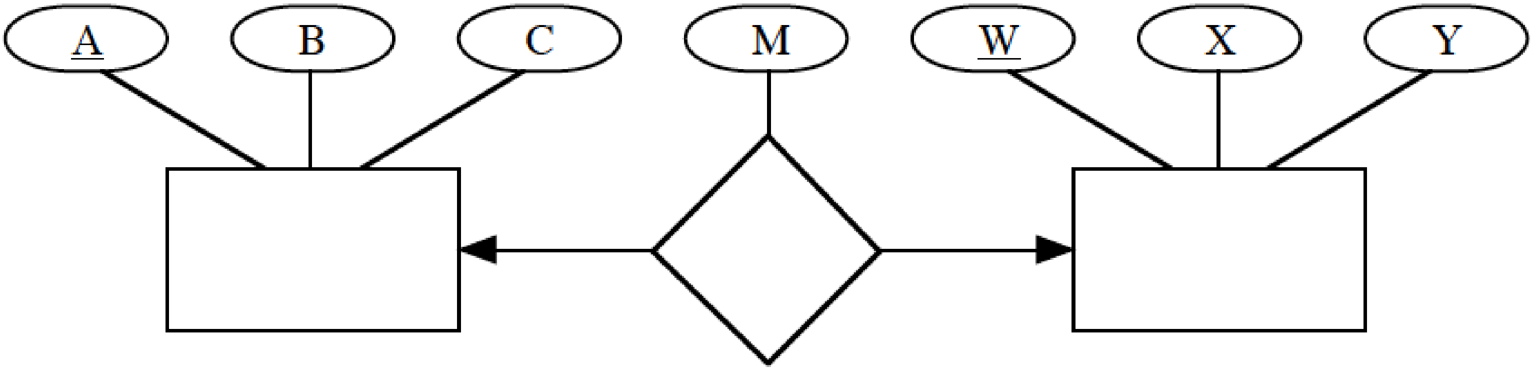
$A \rightarrow BC$

FDs from One to Many / Many to One Relationships



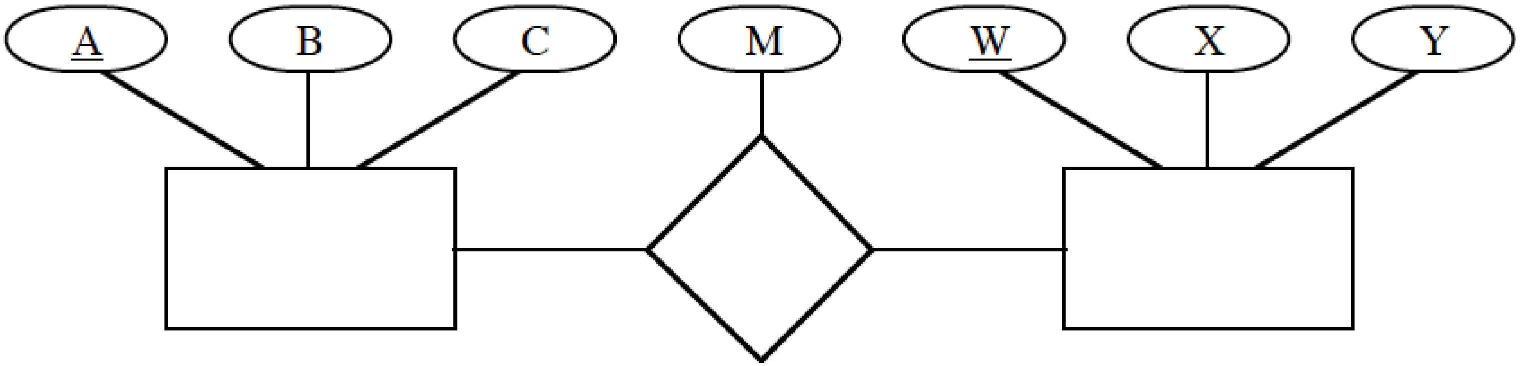
A → BC
W → XY
A → BCMWXY

FDs from One to One Relationships



$A \rightarrow BC$
$W \rightarrow XY$
$A \rightarrow BCMWXY$
$W \rightarrow XYMABC$

FDs from Many to Many Relationships



$A \rightarrow BC$
$W \rightarrow XY$
$AW \rightarrow M$

Implied Functional Dependencies

- Initial set of FDs *logically implies* other FDs
  - If $A \rightarrow B$ and $B \rightarrow C$, then $B \rightarrow C$
- Closure
  - If F is the set of functional dependencies we develop from the logic of the underlying reality
  - Then F+ (the *transitive closure* of F) is the set consisting of all the dependencies of F, plus all the dependencies they imply

Rules for Computing F+

- We can find $F^{+,}$ the closure of F, by repeatedly applying **Armstrong's Axioms:**
  - if $\beta \subseteq \alpha$, then $\alpha \rightarrow \beta$ (**reflexivity**)
    - *Trivial dependency*
  - if $\alpha \rightarrow \beta$, then $\gamma\, \alpha \rightarrow \gamma\, \beta$ (**augmentation**)
  - if $\alpha \rightarrow \beta$, and $\beta \rightarrow \gamma$, then $\alpha \rightarrow \gamma$ (**transitivity**)
- Additional rules (inferred from Armstrong's Axioms)
  - If $\alpha \rightarrow \beta$ *and* $\alpha \rightarrow \gamma$, then $\alpha \rightarrow \beta\gamma$ (**union**)
  - If $\alpha \rightarrow \beta\gamma$, then $\alpha \rightarrow \beta$ and $\alpha \rightarrow \gamma$ (**decomposition**)
  - If $\alpha \rightarrow \beta$ *and* $\gamma\, \beta \rightarrow \delta$, then $\alpha\, \gamma \rightarrow \delta$ (**pseudotransitivity**)