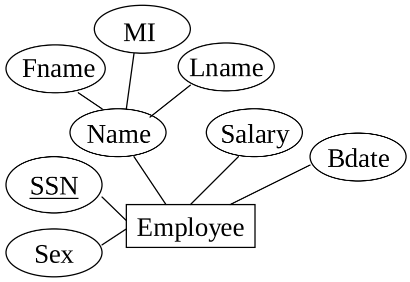
CSC 742
Database Management Systems

Topic #6:
Database Design

Mapping ER Diagrams to Relations

- Regular Entity Type
  - Create a relation R
  - Include simple attributes and simple components of composite attributes
  - Choose one of the key attributes as the primary key
  - Multi-valued attributes:
    - Don’t include in R
    - To be discussed later.

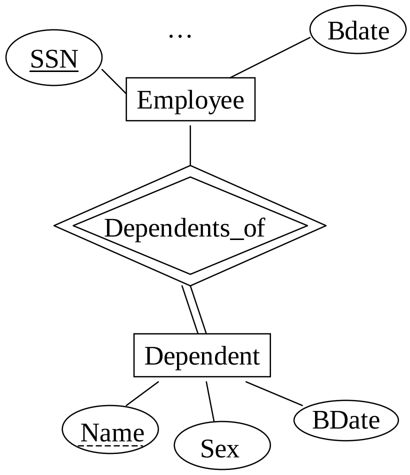
Exercise



Mapping ER Diagrams to Relations (Cont'd)

- Weak Entity Type E
  - Create a relation R
  - Include all simple attributes and simple components of composite attributes.
  - Include the primary key of the relation corresponding to the owner entity type of E.

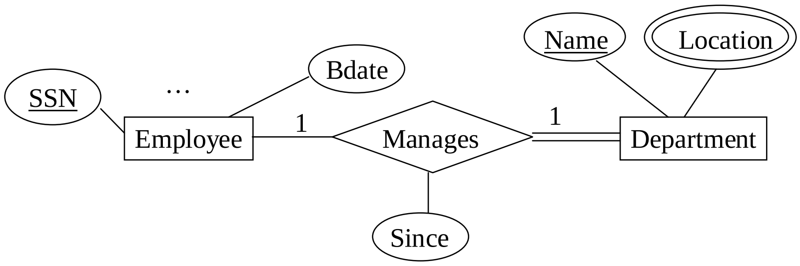
Exercise



Mapping ER Diagrams to Relations (Cont’d)

- Binary 1:1 relationship R
  - Suppose S and T are the relations corresponding to the entity types participating R
  - Choose either S (or T), and include the primary of T (or S) as foreign key.
  - Include the simple attributes and the simple components of composite attributes of R.
  - Better to choose the one with total participation in R.

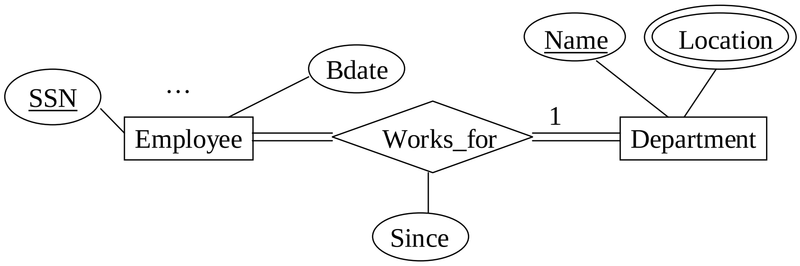
Exercise



Mapping ER Diagrams to Relations (Cont’d)

- Binary 1:N relationship R
  - Suppose S and T are the relations corresponding to the entity types participating R, and S is the N-side.
  - Choose either S, and include the primary key of T as foreign key in S.
  - Include simple attributes and simple components of composite attributes in S.

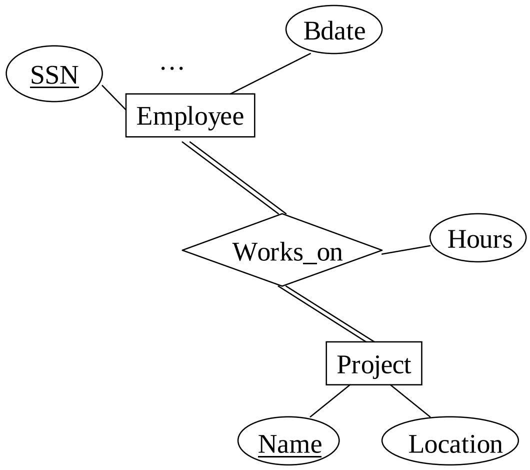
Exercise



Mapping ER Diagrams to Relations (Cont'd)

- Binary M:N relationship R
  - Suppose S and T are the relations corresponding to the entity types participating R
  - Create a relation U
  - Include in U the primary keys of both S and T as foreign keys. They form the primary key of U.
  - Include the simple attributes and the simple components of composite attributes of R.

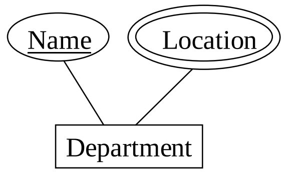
Exercise



Mapping ER Diagrams to Relations (Cont’d)

- Multi-valued attribute A
  - Suppose A is an attribute of the entity type corresponding relation S.
  - Create a relation R
  - Include an attribute corresponding to A and the primary key K of S as a foreign key.
  - The primary key of R is the combination of A and K.

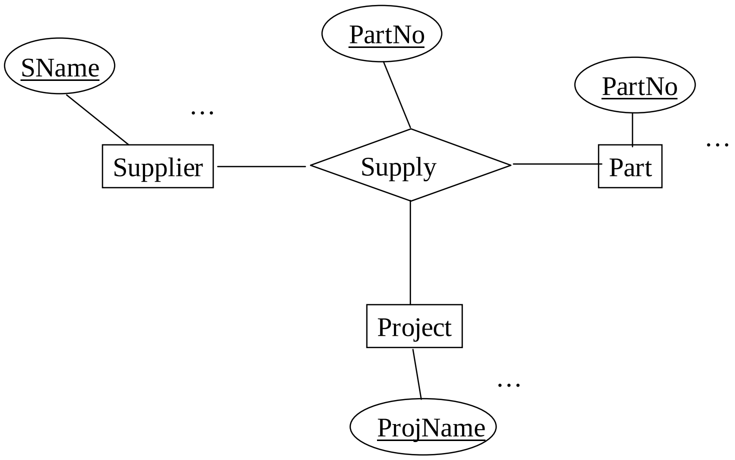
Exercise



Mapping ER Diagrams to Relations (Cont'd)

- The n-ary relationship R
  - Create a new relation S
  - Include the primary keys of all the relations corresponding to the participating entity types in R. They form the primary key of S
  - Include the simple attributes and the simple components of composite attributes of R.

Exercise



Mapping EER Diagrams to Relations

- Subclass-superclass relationships:
  - Commonly four options
  - Assume there are a super-class C and m subclasses {S1, S2, …, Sm}.
  - Assume the attributes of C are {k, a1, …, an}, and k is the key attribute.

Mapping EER Diagrams to Relations (Cont’d)

- Option 1
  - Create a relation L for C with all its attributes, and have k as the primary key.
  - For each subclass Si, create a relation Li with attributes k and all the attributes of Si. The primary key of Si is k.
  - Intuition: keep the attributes of the individual classes separately.

Mapping EER Diagrams to Relations (Cont’d)

- Option 2
  - For each subclass Si, create a relation Li with all the attributes of C and all the attributes of Si. The primary key of Si is k.
  - Intuition: replicate the attributes of the super-class in subclasses.

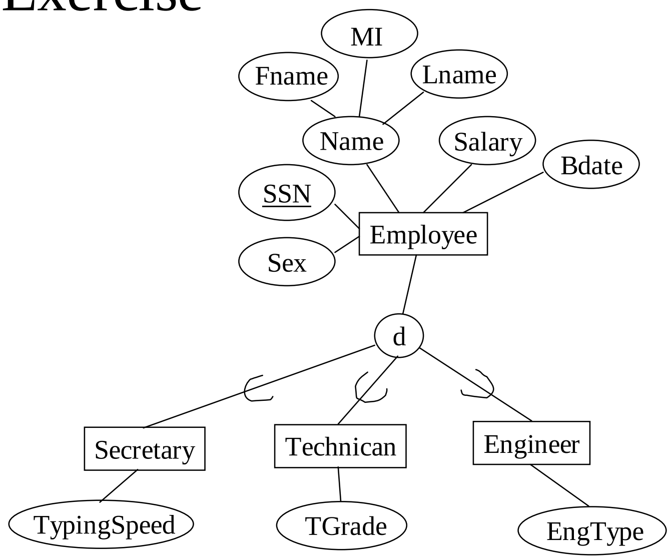
Mapping EER Diagrams to Relations (Cont'd)

- Option 3
  - Create a single relation with the attributes of the super-class and all the subclasses plus a type attribute.
  - The type attribute is used to indicate the subclass to which each tuple belong.
  - Intuition:
    - store all classes together.
    - For disjoint specialization.

Mapping EER Diagrams to Relations (Cont'd)

- Option 4
  - Create a single relation with the attributes of the super-class and all the subclasses plus m type attributes.
  - The type attributes boolean attributes indicating whether the tuple belongs to the corresponding subclasses.
  - Intuition:
    - Store all classes together.
    - For overlapping specialization.

Exercise



Mapping EER Diagrams to Relations (Cont'd)

- Multiple inheritance:
  - all superclasses have the same key

Design Guidelines

- Have schemas that are easy to explain.
  - Keep different entities and relationships apart where possible—at least in base relations
- Prevent anomalies in
  - insertion
  - deletion
  - modification

Employee

Name	SSN	Bdate	DNumber
Smith	111-22-3333	01/11/71	1
Tom	222-33-4444	02/14/68	1

Department

DName	DNumber	MgrSSN
Research	1	111-22-3333

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Name	SSN	Bdate	DNumber	DName	MgrSSN
Smith	111-22-3333	01/11/71	1	Research	111-22-3333
Tom	222-33-4444	02/14/68	1	Research	111-22-3333

Design Guidelines (Cont'd)

- Avoid NULL values in base relations, although they may occur in views. NULLs should apply rarely and have well-defined meaning:
  - Not applicable
  - unknown
  - absent (known but absent)
- Prevent spurious tuples

Registration

StudentID	Name	Course	Location
1	Smith	CSC101	V 150
1	Smith	CSC102	V 100
2	John	CSC101	V 150

Reg1

StudentID	Name	Course
1	Smith	CSC101
1	Smith	CSC102
2	John	CSC101

Loc

StudentID	Location
1	V 150
1	V 100
2	V 150

Functional Dependencies

- A constraint
- R is treated as a set of attributes below
  - For subsets X and Y of R, $X \rightarrow Y$ means that

    For all relations r of R, (forall t1, t2: t1, t2 in r $\Rightarrow$ (t1[X] = t2[X] $\Rightarrow$ t1[Y] = t2[Y]))
- FDs depend on R and its meaning, not on r.

Registration

<u>StudentID</u>	Name	<u>Course</u>	Location
1	**Smith**	**CSC101**	**V 150**
1	**Smith**	**CSC102**	**V 100**
2	**John**	**CSC101**	**V 150**

- Course → Location
- StudentID→Name
- X→Y: The vales of the Y component of a tuple are determined by the values of the X component.
- Alternative statements
  - The values of X *functionally determines* the values of Y.
  - Y is *functionally dependent on* X.
  - There is *functional dependence* from X to Y.

Reasoning With FDs: 1

FDs can be inferred from other FDs.

- Let F be a set of FDs
- $X \rightarrow Y$ is inferred from F if $X \rightarrow Y$ holds in every relation r that satisfies F
  - (notation: $F \models X \rightarrow Y$)
- F+ is the set of all FDs that can be inferred from F.
  - Called the closure of F.

Reasoning With FDs: 2

FDs can be inferred based on

- Their formal definition
- Armstrong's rules:
  - Reflexivity: If X contains Y, then $X \rightarrow Y$
  - Augmentation: $\{X \rightarrow Y\} \models XZ \rightarrow YZ$
  - Transitivity: $\{X \rightarrow Y, Y \rightarrow Z\} \models X \rightarrow Z$
- which are provably complete.

Reasoning With FDs: 3

- Additional Inference Rules:
  - Decomposition rule
    - $\{X \rightarrow YZ\} \models X \rightarrow Y$.
  - Union rule
    - $\{X \rightarrow Y, X \rightarrow Z\} \models X \rightarrow YZ$
  - Pseudo-transitive rule
    - $\{X \rightarrow Y, WY \rightarrow Z\} \models WX \rightarrow Z$.

Find Additional FDs

- Given a set F of FDs,
  - For each set of attributes X that appears as a left-hand side of an FD in F,
  - Determine the set X^+ of attributes that are functionally determined by X based on F.
  - X^+: the closure of X under F.
  - Algorithm to compute X^+ under F.
  - $X^+ := X$;
  - Repeat
    - $OldX^+ := X^+$
    - For each FD $Y \rightarrow Z$ in F do
      - If $X^+ \supseteq Y$ then $X^+ := X^+ \cup Z$
    - Until ($X^+ = oldX^+$)

Minimal Cover

- Equivalence of sets of FDs
  - Two sets of functional dependencies E and F are equivalent if $E^+ = F^+$.
- A set F of FDs is *minimal* if
  - Every FD in F has a single attribute for the right-hand side
  - We cannot replace any $X \rightarrow A$ with $Y \rightarrow A$, where $Y \subset X$, and still have a set of FDs equivalent to F.
  - We cannot remove any FD from F and still have a set of FDs equivalent to F.

Minimal Cover (Cont'd)

- A *minimal cover* of a set F of FDs is a minimal set of FDs that is equivalent to F.
  - Always exist.
- Algorithm 14.2 in textbook
  - Step 1.
  - Step 2. Change the FDs to those with one attribute on the right-hand side.
  - Step 3. Try to remove attributes from the left-hand sides of FDs.
  - Step 4. Try to remove redundant FDs.

Normalization

- A process of cleaning up a schema by decomposing the relations in it
  - to remove various anomalies
  - but additional considerations apply
- A schema is in some normal form if it satisfies the specified mathematical properties and thereby avoids some potential anomalies

Keys

- S is a superkey of R = {A1, ..., An} iff
  - R contains S
  - (forall t1, t2: t1[S] = t2[S] $\Rightarrow$?)
- K is a (candidate) key or identifier of R iff
  - K is a superkey
  - (forall L: K contains L $\Rightarrow$?)
- The primary key is one of the candidate keys.

Achtung!

Prime attribute

- member of any key
- not just the primary key

1NF

- Attributes must be atomic:
  - they can be chars, ints, strings
  - they can't be
    - tuples
    - sets
    - relations
    - composite
    - multivalued

Obtaining 1NF

1NF is obtained by

- Splitting composite attributes
- splitting the relation and propagating the primary key to remove multivalued attributes

Full FD

- $X \rightarrow Y$ is a full FD if
  - (forall W: (X contains W & $W \rightarrow Y$) $\Rightarrow$ X = W)
- $X \rightarrow Y$ is a partial FD, otherwise

2NF

- R is in 2NF if every nonprime attribute is fully functionally dependent on every key of R
- Note that every attribute must be functionally dependent on every key (by definition of a key)

Obtaining 2NF

- If a nonprime attribute is dependent only on a proper part of a key, then we take the given attribute as well as the key attributes that determine it and move them all to a new relation
- We can bundle all attributes determined by the same subset of the key as a unit

Exercise

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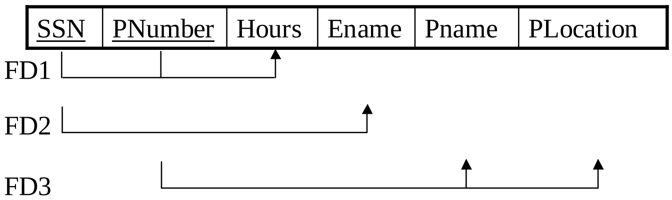

3NF

R is in 3NF if and only if

- if X → A then
  - X is a superkey of R, or
  - A is a prime attribute of R

Transitive Dependency

- $X \rightarrow Y$ is a transitive dependency if
  - (exists Z: Z is not contained in any key of R & $X \rightarrow Z$ and $Z \rightarrow Y$)

3NF: Alternative Definition

- R is in 3NF if every nonprime attribute of R is
  - fully functionally dependent on every key of R, and
  - nontransitively dependent on every key of R.

Obtaining 3NF

- Split off the attributes in the FD that causes trouble and move them, so there are two relations for each such FD
- The determinant of the FD remains in the original relation

Exercise

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Ename	<u>SSN</u>	BDate	Address	DNumber	DName	DMgrSSN

BCNF

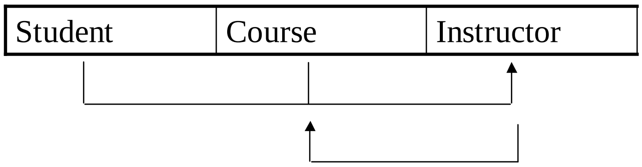
R is in Boyce-Codd Normal Form iff

- if $X \rightarrow A$ then
  - X is a superkey of R
- more restrictive than 3NF
  - preferable—has fewer anomalies

Obtaining BCNF

- As usual, split the schema to move the attributes of the troublesome FD to another relation, leaving its determinant in the original so they remain connected
  - not always attainable

Exercise



Universal Relation: 1

- A *universal relation* is a single giant relation containing the entire database
  - has all attributes (renamed to be unique)
  - has enough tuples with NULL values as appropriate
  - not used in practice
  - only a theoretical construct!

Universal Relation: 2

- One way to think about DB design is to imagine that we begin with the universal relation and normalize the schema to whatever level we like
  - theoretically interesting
  - partially usable
  - should not be the only tool in one's DB design