

Multivalued Dependencies

Fourth Normal Form

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A New Form of Redundancy

- ◆ Multivalued dependencies (MVD's) express a condition among tuples of a relation that exists when the relation is trying to represent more than one many-many relationship.
- ◆ Then certain attributes become independent of one another, and their values must appear in all combinations.

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Example

Drinkers(name, addr, phones, beersLiked)

- ◆ A drinker's phones are independent of the beers they like.
- ◆ Thus, each of a drinker's phones appears with each of the beers they like in all combinations.
- ◆ This repetition is unlike redundancy due to FD's, of which name->addr is the only one.

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Tuples Implied by Independence

If we have tuples:

<u>name</u>	<u>addr</u>	<u>phones</u>	<u>beersLiked</u>
sue	a	p1	b1
sue	a	p2	b2
sue	a	p2	b1
sue	a	p1	b2

Then these tuples must also be in the relation.

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Definition of MVD

- ◆ A *multivalued dependency* (MVD) $X \twoheadrightarrow Y$ is an assertion that if two tuples of a relation agree on all the attributes of X , then their components in the set of attributes Y may be swapped, and the result will be two tuples that are also in the relation.

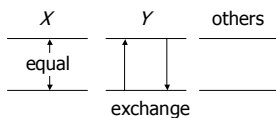
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Example

- ◆ The name-addr-phones-beersLiked example illustrated the MVD
name->>phones
and the MVD
name->>beersLiked.

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Picture of MVD $X \twoheadrightarrow Y$



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MVD Rules

- ◆ Every FD is an MVD.
 - ◆ If $X \rightarrow Y$, then swapping Y 's between two tuples that agree on X doesn't change the tuples.
 - ◆ Therefore, the "new" tuples are surely in the relation, and we know $X \twoheadrightarrow Y$.
- ◆ *Complementation*: If $X \twoheadrightarrow Y$, and Z is all the other attributes, then $X \twoheadrightarrow Z$.

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Splitting Doesn't Hold

- ◆ Like FD's, we cannot generally split the left side of an MVD.
- ◆ But unlike FD's, we cannot split the right side either --- sometimes you have to leave several attributes on the right side.

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Example

- ◆ Consider a drinkers relation:
Drinkers(name, areaCode, phone, beersLiked, manf)
- ◆ A drinker can have several phones, with the number divided between areaCode and phone (last 7 digits).
- ◆ A drinker can like several beers, each with its own manufacturer.

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Example, Continued

- ◆ Since the areaCode-phone combinations for a drinker are independent of the beersLiked-manf combinations, we expect that the following MVD's hold:
 - name \twoheadrightarrow areaCode phone
 - name \twoheadrightarrow beersLiked manf

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Example Data

Here is possible data satisfying these MVD's:

name	areaCode	phone	beersLiked	manf
Sue	650	555-1111	Bud	A.B.
Sue	650	555-1111	WickedAle	Pete's
Sue	415	555-9999	Bud	A.B.
Sue	415	555-9999	WickedAle	Pete's

But we cannot swap area codes or phones by themselves. That is, neither name \twoheadrightarrow areaCode nor name \twoheadrightarrow phone holds for this relation.

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Fourth Normal Form

- ◆ The redundancy that comes from MVD's is not removable by putting the database schema in BCNF.
- ◆ There is a stronger normal form, called 4NF, that (intuitively) treats MVD's as FD's when it comes to decomposition, but not when determining keys of the relation.

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4NF Definition

- ◆ A relation R is in 4NF if whenever $X \twoheadrightarrow Y$ is a nontrivial MVD, then X is a superkey.
 - ◆ "Nontrivial means that:
 1. Y is not a subset of X , and
 2. X and Y are not, together, all the attributes.
 - ◆ Note that the definition of "superkey" still depends on FD's only.

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BCNF Versus 4NF

- ◆ Remember that every FD $X \rightarrow Y$ is also an MVD, $X \twoheadrightarrow Y$.
- ◆ Thus, if R is in 4NF, it is certainly in BCNF.
 - ◆ Because any BCNF violation is a 4NF violation.
- ◆ But R could be in BCNF and not 4NF, because MVD's are "invisible" to BCNF.

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Decomposition and 4NF

- ◆ If $X \twoheadrightarrow Y$ is a 4NF violation for relation R , we can decompose R using the same technique as for BCNF.
 1. XY is one of the decomposed relations.
 2. All but $Y - X$ is the other.

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Example

Drinkers(name, addr, phones, beersLiked)

FD: name \rightarrow addr

MVD's: name \twoheadrightarrow phones

name \twoheadrightarrow beersLiked

- ◆ Key is {name, phones, beersLiked}.
- ◆ All dependencies violate 4NF.

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Example, Continued

- ◆ Decompose using name \rightarrow addr:
 1. Drinkers1(name, addr)
 - ◆ In 4NF, only dependency is name \rightarrow addr.
 2. Drinkers2(name, phones, beersLiked)
 - ◆ Not in 4NF. MVD's name \twoheadrightarrow phones and name \twoheadrightarrow beersLiked apply. No FD's, so all three attributes form the key.

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Example: Decompose Drinkers2

◆ Either MVD name → phones or name → beersLiked tells us to decompose to:

- ◆ Drinkers3(name, phones)
- ◆ Drinkers4(name, beersLiked)