CSC7072: Databases, fall 2015

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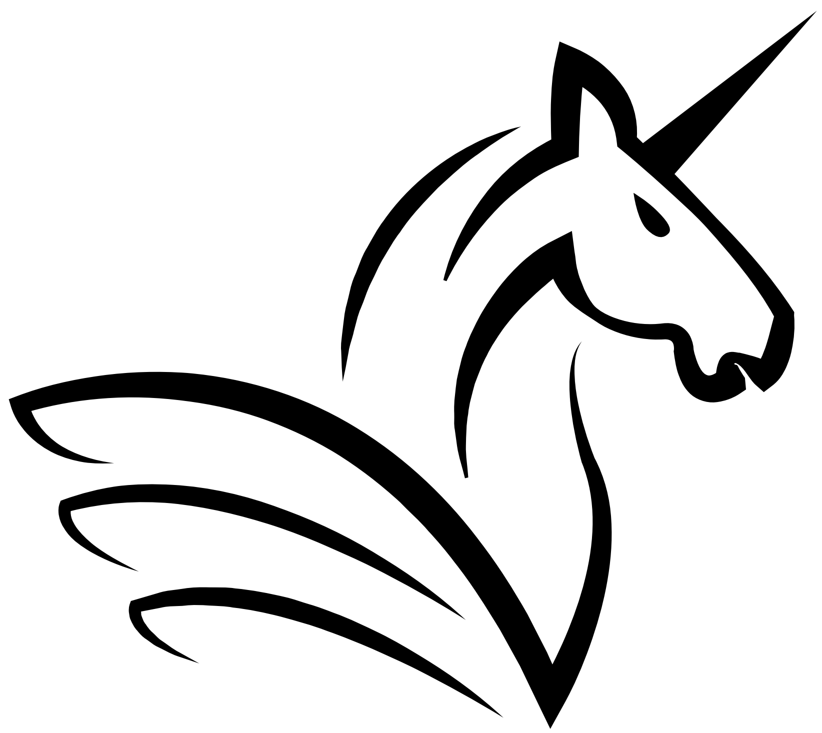
normalisation

Normalisation

adding tables using SQL

we learned how to convert an ER model to a relation model



why do you believe that this is a good approach?

Normalisation

normalisation levels

what is normalisation?

it is a formal process to identify a good database,
and to improve a database design if any issues are found

1st normal form (1NF)
2nd normal form (2NF)
3rd normal form (3NF)
3.5th normal form (BCNF)
4th normal form (4NF)
5th normal form (5NF)

gets harder: more conditions to satisfy

gets better: less anomalies with update/insert/delete

gets worse: possible drop in performance

Normalisation

normalisation levels

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Normalisation

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1^{st} normal form (1NF)
2^{nd} normal form (2NF)
3^{rd} normal form (3NF)

achievable by all DB

3.5^{th} normal form (BCNF)
4^{th} normal form (4NF)
5^{th} normal form (5NF)

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Normalisation

problems we try to avoid

what do we want to achieve?

- we want to minimise (even eliminate) redundant information
  having redundant information would make updates more difficult as we need to make sure *everything* is changed correctly

- we want to achieve representational power
  we want to be able to put all our required data in the database!

- we want to avoid loss of information
  we can keep on splitting tables into smaller ones, but as some point we won't be able to piece the information back together!

Normalisation

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id	name	dept_name	salary	dept_budget
45039	John	Comp. Sci.	65000	450000
30594	Selma	Comp. Sci.	75000	450000
30492	Paul	Elec. Eng.	90000	720000
20996	Tisan	Elec. Eng.	80000	720000

better not forget to update both!

Normalisation

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better not forget to update both!

and you will …

Normalisation

problems we try to avoid

what do we want to achieve?

John can be reached on 074 1000 1000, or 028 1000 1000

oops …

- we want to achieve representational power
  we want to be able to put all our required data in the database!

id	name	dept_name	salary	tel_no
45039	John	Comp. Sci.	65000	074 1000 1000
30594	Selma	Comp. Sci.	75000	074 2000 2000
30492	Paul	Elec. Eng.	90000	074 3000 3000
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Normalisation

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id	name	dept_name	salary
45039	Kim	Comp. Sci.	40000
30594	Kim	Elec. Eng.	50000

id	name
45039	Kim
30594	Kim

name	dept_name	salary
Kim	Comp. Sci.	40000
Kim	Elec. Eng.	50000

Normalisation

problems we try to avoid

avoiding loss of information

id	name
45039	Kim
30594	Kim

name	dept_name	salary
Kim	Comp. Sci.	40000
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↘ join ↙

id	name	dept_name	salary
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lossy decomposition: no longer gives us original table after join

Normalisation

why they exist

main idea of normalisation:

- verify if a schema is in a *"good"* form
- if not, decompose the relation in multiple relations using a lossless decomposition

some notions we will use:

a *non-key* attribute is an attribute that is not a part of the primary key or any candidate key

a *functional dependency*, written as X → Y … Z, means that the values of Y … Z are determined by the values of X (the *determinant*).

in other words: X would be a candidate key for table(X, Y, Z)
or also: the same <u>student_id</u> will always give us the same row

Normalisation

1NF: atomic values

first normal form (1NF)

definition
A relation is in first normal form if the domain of each attribute contains only atomic values, and the value of each attribute contains only a single value from that domain.

a domain is *atomic* if its elements are considered *indivisible* units

examples of non-atomic data:

- a set of telephone numbers, a composite attribute
- CS7052: this is department CS and id 7052 !

Normalisation

1NF: atomic values

first normal form (1NF)

definition

A relation is in first normal form if the domain of each attribute contains only atomic values, and the value of each attribute contains only a single value from that domain.

always assumes data to be atomic, but also:

- there are no duplicate rows/columns
- all records have the same number of attributes

(but this really is by definition of using relation schemas)

Normalisation

2NF: non-key attributes depend on the entire PK

second normal form (2NF)

definition

A relation is in second normal form when we do not have a *non-key attribute* that depends on a *strict subset* of the *primary key*.

<u>part</u>	<u>warehouse</u>	quantity	address
1021	alpha	512	infinity loop
0023	alpha	256	infinity loop
0587	beta	192	redmond
1021	gamma	1024	mountain view

Normalisation

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Normalisation

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problem:

a functional dependency: warehouse → address

indicates the need to decompose!

solution:

inventory_part(<u>part</u>, <u>warehouse</u>, quantity)

inventory_warehouse(<u>warehouse</u>, location)

Normalisation

3NF: non-key attributes depend *only* on the entire PK

third normal form (3NF)

definition

A relation is in third normal form when we do not have a *non-key attribute* that is a fact about another *non-key attribute*

<u>employee_id</u>	department	location
12345	Comp. Sci.	ECS
10001	Comp. Sci.	ECS
34021	Elec. Eng.	ECIT
60520	Elec. Eng.	ECIT

Normalisation

3NF: non-key attributes depend *only* on the entire PK

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department → location

so … decompose!

Normalisation

3NF: non-key attributes depend *only* on the entire PK

third normal form (3NF)

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A relation is in third normal form when we do not have a *non-key attribute* that is a fact about another *non-key attribute*

solution:

employee_department(employee_id, department)

department(department, location)

conclusion: a schema is in (2nd and) 3rd normal form when every field is either part of the primary key or provides a single-valued fact *about the whole key and nothing else*

Normalisation

BCNF: all determinants must be candidate keys

Boyce-Codd normal form (BCNF): *overlapping candidate keys*

definition

A relation is in Boyce-Codd normal form when every attribute provides a fact about the whole key, *or*, if and only if every determinant is a candidate key.

example:

supervision(<u>project</u>, <u>branch</u>, manager)

❶ manager → branch	each manager works in one branch
❷ project, branch → manager	each project has several managers and spans several branches; a project has a unique manager for every branch

Normalisation

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not in BCNF!

Normalisation

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1. manager → branch
2. project, branch → manager

not in BCNF!

candidate keys:

project, branch

project, manager

Normalisation

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prevents decomposition

Normalisation

strong entity, composite and derived attributes

3NF or Boyce-Codd normal form?

always possible to convert a DB into 3NF where:

- the decomposition is lossless;
- all functional dependencies are preserved; but where
- some anomalies occur …
  e.g. a branch is involved in multiple projects; a manager changes branch …

always possible to convert a DB into BCNF where:

- the decomposition is lossless; but only
- ***some*** functional dependencies are preserved …

Normalisation

strong entity, composite and derived attributes

goal for a relational database design:

- achieve BCNF; with
- lossless decomposition; *and*
- full functional dependency preservation

if that is impossible, then choose:

- stick to 3NF and full functional dependency preservation
  be wary of the anomalies!

- get BCNF but miss out on some functional dependencies
  might not be able to represent all information!

Normalisation

4NF: non-key attributes must depend on each other and the PK

fourth normal form (4NF)

definition

A relation is in fourth normal form when it does not have more than one multivalued dependency.

restaurant	variety	delivery_area
A1 Pizza	Thick Crust	Shelbyville
A1 Pizza	Thick Crust	Capital City
A1 Pizza	Stuffed Crust	Shelbyville
A1 Pizza	Stuffed Crust	Capital City
Elite Pizza	Thin Crust	Capital City
Elite Pizza	Stuffed Crust	Capital City

multivalued dependency:

if we choose a restaurant, then we know the variety (which does not depend on the delivery area), and vice versa

Normalisation

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Elite Pizza	Stuffed Crust	Capital City

multivalued dependency:

restaurant $\twoheadrightarrow$ variety

restaurant $\twoheadrightarrow$ delivery_area

Normalisation

4NF: non-key attributes must depend on each other and the PK

fourth normal form (4NF)

definition

A relation is in fourth normal form when it does not have more than one multivalued dependency.

delivery(restaurant, variety, delivery_area)

decompose

varieties(restaurant, variety)

delivery_area(restaurant, delivery_area)

Normalisation

5NF: the relation consists only of a PK and a non-key attribute

fifth normal form (5NF)

definition

A relation is in fifth normal form if decomposing it in any possible way would not remove any redundancies.

by far, one of the most elusive normal forms to understand

easiest is just to try out all possible decompositions, and make sure none of them are lossy decompositions

it tends to create too many small tables, which is great for updating and absolutely horrible for performance (umpteen joins!)

Normalisation

ER models and normalisation

is normalisation needed for E-R models?

- **when** an E-R model is well-designed (*i.e.* all entities and relations are correctly identified) **then** the tables generated from an E-R model should not need normalisation
- in the real world, the design is imperfect and some functional dependencies will still be left
  e.g. employee(id, name, dept_name, building)
  where dept_name → building

so E-R model is *generation*, normalisation is *verification*

Normalisation

how best to use normalisation

how to design a good database

1. start from a relation model:
   - we can obtain this as the result of an E-R model; or
   - we can have a single relation with all relevant attributes
     i.e. one big table, called the universal relation

2. normalise this relation model to break it into smaller relations

3. stop when the desired normalisation form is reached
   - no excuse to stop before 3NF!
   - always apply 3.5NF if possible
   - 4NF and 5NF provide trade-offs: anomalies/performance