RDBMS and SQL

Madhavan Mukund

https://www.cmi.ac.in/~madhavan

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Relational database design

- Set of attributes that one needs to keep track of
- Why not combine into a single table?

Relational database design

Instructor

ID	*name*	*dept_name*	*salary*
10101	Srinivasan	Comp. Sci.	65000
12121	Wu	Finance	90000
15151	Mozart	Music	40000
22222	Einstein	Physics	95000
32343	El Said	History	60000
33456	Gold	Physics	87000
45565	Katz	Comp. Sci.	75000
58583	Califieri	History	62000
76543	Singh	Finance	80000
76766	Crick	Biology	72000
83821	Brandt	Comp. Sci.	92000
98345	Kim	Elec. Eng.	80000

Department

dept_name	*building*	*budget*
Biology	Watson	90000
Comp. Sci.	Taylor	100000
Elec. Eng.	Taylor	85000
Finance	Painter	120000
History	Painter	50000
Music	Packard	80000
Physics	Watson	70000

- Combine these into a single table?

Relational database design

- Redundant storage
- Maintaining consistency
  - Updates
  - Inserts and deletes

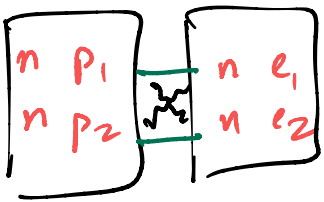
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Update budget for CS

Ideally only one source of truth

Decomposition and information

- (customer_name,regd_phone,regd_email)
- Decompose as (customer_name,regd_phone) and (customer_name,regd_email)
- Name is not unique — loss of information
- Recombining decomposed relation should not add tuples
- Lossless decomposition
  - Decompose R as R_1 and R_2
  - Want $R = R_1 \bowtie R_2$



Name Phone Email

n p1 e1

n p2 e2

Functional dependencies

- $A_1, A_2, \ldots, A_k \rightarrow B_1, B_2, \ldots B_m$
  - LHS atributes uniquely fix RHS attributes
  - Must hold for every instance — semantic property of attributes
- Need not correspond to superkeys
  - dept_name → building
  - dept_name → budget

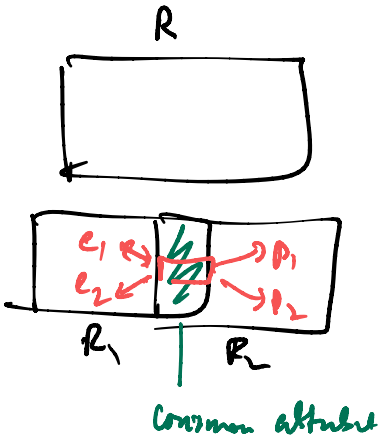
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- Use to identify sources of redundancy, guide decomposition

Lossless decomposition and functional dependencies

- Decompose R as R_1 and R_2
- Decomposition is lossless if at least one of the following functional dependencies hold
  - $R_1 \cap R_2 \rightarrow R_1$
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- In general need to compute all implied dependencies
  - From $A \rightarrow B$ and $B \rightarrow C$, conclude that $A \rightarrow C$
- Closure of a set of dependencies F — denoted F^+

Axioms

if $A \rightarrow B$, $A \rightarrow C \Rightarrow A \rightarrow B, C$

$A \rightarrow B$, $B \rightarrow C \Rightarrow A \rightarrow C$

dept_name → bldg

dept_name → budget

↓

dept → bldg, budg

sets ? attributes

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Armstrong's axioms — Soundness
Nothing wrong is derived
— Completeness
All valid consequences are derived

Computing the closure of a set of attributes

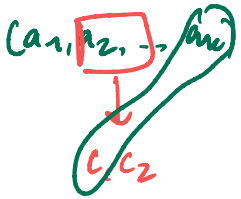
- Given $\mathcal{A} = \{A_1, A_2, \ldots, A_k\}$ and B, does $A_1, A_2, \ldots, A_k \rightarrow B$?

Given F

Computing the closure of a set of attributes

- Given $\mathcal{A} = \{A_1, A_2, \ldots, A_k\}$ and B, does $A_1, A_2, \ldots, A_k \rightarrow B$?
- Iterative algorithm — check if B is in closure $\mathcal{A}^+$

Initialize $\mathcal{A}^+$ to $\{A_1, A_2, \ldots, A_k\}$
repeat
  for each $\beta \rightarrow \gamma$ in F
    if $\beta \subseteq \mathcal{A}^+$, add γ to $\mathcal{A}^+$
  end
until no change in $\mathcal{A}^+$



Why does it terminate? — total set of attributes is finite

What about $F \Rightarrow F^+$?

Computing the closure of a set of attributes

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$(R_1 \cap R_2) \rightarrow R_1$ really means $(R_1 \cap R_2) \rightarrow R_1 \in F^+$

Computing the closure of a set of attributes

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Armstrong's axioms — Expand F to F^+

- How do we use this to compute F^+, the closure of F?

Computing the closure of a set of attributes

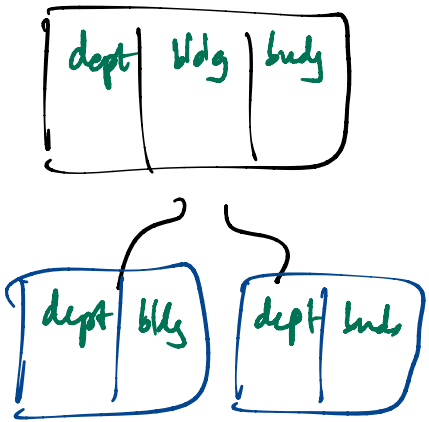
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- How do we use this to compute F^+, the closure of F?
  - For each subset of attributes X, compute X^+
  - For each subset Y of X^+, add dependency $X \rightarrow Y$

Normal forms

- Criteria to determine if the collection of tables is "good"



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- Normalization — decompose tables till they achieve a normal form
- Guided by functional dependencies

Boyce-Codd Normal Form (BCNF)

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- Write α, β to represent sequences of attributes $A_1, A_2, \ldots, A_k$, $B_1, B_2, \ldots, B_m$

Boyce-Codd Normal Form (BCNF)

- Relational schema R, set of functional dependencies F — single relation in our database
- Write α, β to represent sequences of attributes $A_1, A_2, \ldots, A_k$, $B_1, B_2, \ldots, B_m$
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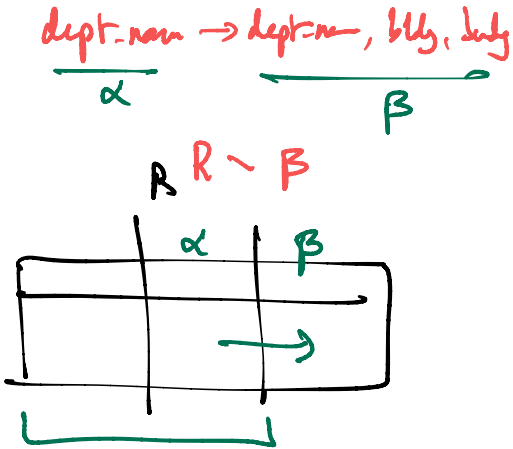
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- `InstructorDepartment(ID,name,salary,dept_name,building,budget)` not in BCNF
  - `dept_name` $\rightarrow$ `building, budget` — a key by construction
- `Instructor(ID,name,dept_name,salary)` and `Department(dept_name,building,budget)` are in BCNF

Achieving BCNF

- $\alpha \rightarrow \beta \in F^+$ is a BCNF violation for R if neither of the following holds
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Achieving BCNF

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  - $\alpha \cup \beta$
  - $R \setminus (\beta \setminus \alpha)$



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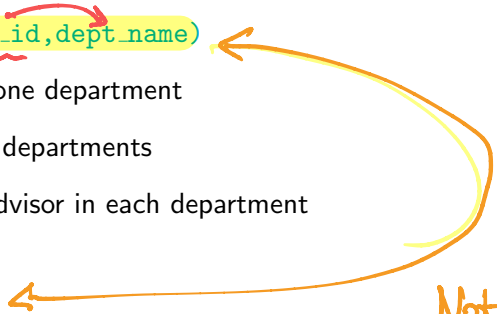
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- Decompose as
  - `Department(dept_name,building,budget)`
  - `Instructor(ID,name,dept_name,salary)`

Dependency preservation

- `Advisor(student_id,faculty_id,dept_name)`
- Each faculty member is in only one department
- Students can be across multiple departments
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  - faculty_id → dept_name
  - student_id,dept_name → faculty_id



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- BCNF decomposition is (student_id,faculty_id), (faculty_id,dept_name)



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- BCNF decomposition is (student_id,faculty_id), (faculty_id,dept_name)
- Need join to check dependency student_id,dept_name $\rightarrow$ faculty_id

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- Let F_i be set of dependencies in F^+ locally checkable in R_i
- Let $G = F_1 \cup F_2 \cup \cdots \cup F_k$. Is $G^+ = F^+$?
- How do we compute F_i for each R_i?
  - Let R_i have attributes $A_1, A_2, \ldots, A_m$
  - For each subset α of $A_1, A_2, \ldots, A_m$, compute α^+ with respect to F^+
  - For each $B \in \alpha^+ \cap \{A_1, A_2, \ldots, A_m\}$, add $\alpha \rightarrow B$ to R_i

Third normal form (3NF)

- R is in 3NF if, for every $\alpha \to \beta \in F^+$, one of the following holds
  - $\alpha \to \beta$ is trivial (i.e., $\beta \subseteq \alpha$)
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BCNF

1NF – All data is "scalar"

2NF ⟹ BCNF

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- BCNF is a stricter condition than 3NF
- Priorities
  - Lossless decomposition
  - BCNF
  - Dependency preservation

Beyond functional dependencies

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- 4NF

Practical matters

- Validating functional dependencies

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- Redundancy vs computing joins — denormalization, materialized views