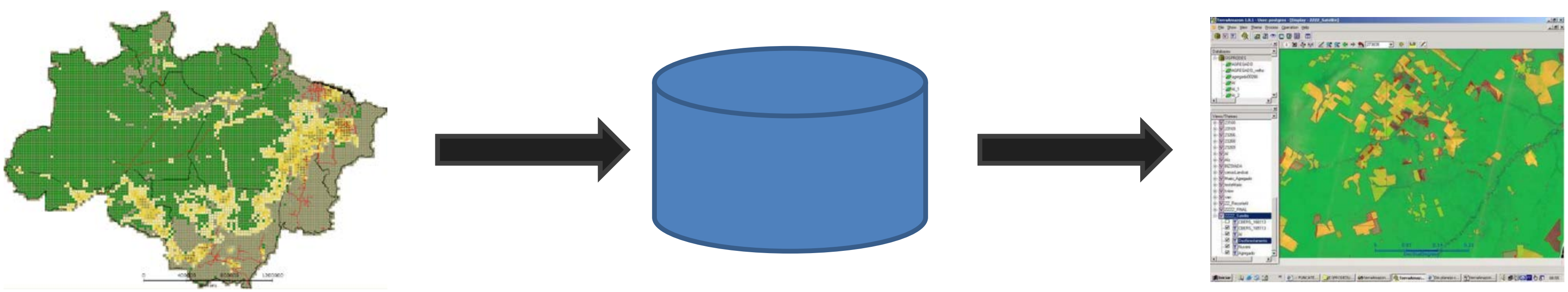
Spatial Databases: Lecture 4

Institute for Geoinformatics

Winter Semester 2014



Malumbo Chipofya: room 109

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Topic Overview

1. Prelude: Data and problem solving in science and applications
2. **The Relational Database model**
3. **Interacting with relational databases**
4. Spatial Relational Database Management Systems
5. Applications: Terraview and Terralib: Prof. Dr. Gilberto Camara
6. A sample of Nosql Databases: brief introductions + example applications
   a. Array databases: SciDB
   b. Document databases: MongoDB
   c. Graph databases: Neo4J
7. Summary of all lectures given.

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Recap

- Candidate Keys:
  – Uniqueness + Irreducibility
- Relational Operations:
  – Restrict + Project + Join
- Functional Dependence: $B \rightarrow A$
  – A is functionally dependent on B
  – B is functionally determines on A

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Functional Dependencies

- Given two sets of attributes of a relation $\boldsymbol{R}$:

  $\boldsymbol{A} := \{\boldsymbol{a}, \boldsymbol{b}, \boldsymbol{c}, \ldots\} \quad \boldsymbol{B} := \{\boldsymbol{x}, \boldsymbol{y}, \boldsymbol{z}, \ldots\}$

- $\boldsymbol{A}$ is a functionally dependent on $\boldsymbol{B}$ written

$$\boldsymbol{B} \rightarrow \boldsymbol{A}$$

if and only if there is a function from the set of legal values of $\boldsymbol{B}$ to the set of legal values of $\boldsymbol{A}$ determined exactly by tuples of $\boldsymbol{R}$

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Functional Dependencies

- Trivial FD
  - $LHS \supseteq RHS$
- The closure of a set S of FDs (denoted S^{+})
  - The set of ***all*** FDs that can be derived from S
  - S^{+} can be computed using few simple rules

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Functional Dependencies

- Rules – we write ‘A’ for {A} and ‘A,B,C’ for {A, B, C}
  - Reflexivity:
    - $B \subseteq A$ implies $A \longrightarrow B$
  - Augmentation:
    - $A \longrightarrow B$ implies $A,C \longrightarrow B,C$
  - Transitivity:
    - $A \longrightarrow B$ and $B \longrightarrow C$ implies $A \longrightarrow C$
  - Self-determination:
    - $A \longrightarrow A$
  - Decomposition:
    - $A \longrightarrow B,C$ implies $A \longrightarrow B$ and $A \longrightarrow C$
  - Union:
    - $A \longrightarrow B$ and $A \longrightarrow C$ implies $A \longrightarrow B,C$
  - Composition:
    - $A \longrightarrow B$ and $C \longrightarrow D$ implies $A,C \longrightarrow B,C$

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Functional Dependencies Example:

$$\{A \rightarrow B, C; C \rightarrow D\}$$

- Reflexivity: B ⊆ A implies A ⟶ B
- Augmentation: A ⟶ B implies A,C ⟶ B,C
  - $A, C \rightarrow A, D$; $A, C \rightarrow B, C$; $A, D \rightarrow B, C, D$; $B, C \rightarrow B, D$
- Transitivity: A ⟶ B and B ⟶ C implies A ⟶ C
  - $A \rightarrow B, D$; $A, C \rightarrow B, D$; $A, C \rightarrow B, C, D$
- Self-determination: A ⟶ A
- Decomposition: A ⟶ B,C implies A ⟶ B and A ⟶ C
  - $A \rightarrow B$; $A \rightarrow C$; $A \rightarrow D$;
- Union: A ⟶ B and A ⟶ C implies A ⟶ B,C
  - $A \rightarrow C, D$;
- Composition: A ⟶ B and C ⟶ D implies A,C ⟶ B,D
  - ***Anything else***?

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Functional Dependencies

- Irreducibility
  - A set of FDs, S, is irreducible if and only if it satisfies
    - RHS of every FD in S has only one attribute
    - LHS of every FD in S is irreducible in the sense that discarding any attribute changes the closure of S – **left irreducibility**
    - Discarding any FD in S changes the closure of S

Functional Dependencies

- Irreducibility: from last example
  - $A, C \rightarrow A, D$
  - $A, C \rightarrow B, C$
  - $A, D \rightarrow B, C, D$
  - $B, C \rightarrow B, D$
  - $A, C \rightarrow B, D$
  - $A, C \rightarrow B, C, D$

Functional Dependencies

- Irreducibility: from last example
  - RHS of every FD in S has only one attribute (Decomposition)
  - $A, C \rightarrow A, D;$
  - $A, C \rightarrow B, C$
  - $A, C \rightarrow B, D$
  - $A, C \rightarrow B, C, D$

    $A, C \rightarrow B;\quad A, C \rightarrow B;\quad A, C \rightarrow D$
  - $A, D \rightarrow B, C, D$

    $A, D \rightarrow B;\quad A, D \rightarrow C;\quad A, D \rightarrow D$
  - $B, C \rightarrow B, D$

    $B, C \rightarrow B;\quad B, C \rightarrow C$

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Functional Dependencies

- Irreducibility: from last example
  - Discarding any FD in S changes the closure of S
    (Discard the trivial FDs + all those that can be derived)
  - $A, C \rightarrow A, D;$
  - $A, C \rightarrow B, C$
  - $A, C \rightarrow B, D$
  - $A, C \rightarrow B, C, D$
  - $A, D \rightarrow B, C, D$
  - $B, C \rightarrow B, D$

$A, C \rightarrow B;\quad A, C \rightarrow C;\quad A, C \rightarrow D$

$A, D \rightarrow B;\quad A, D \rightarrow C;\quad A, D \rightarrow D$

$B, C \rightarrow B;\quad B, C \rightarrow D$

Functional Dependencies

- Irreducibility: from last example
  - Discarding any attribute on LHS changes the closure of S – **left irreducibility**
  - $A, C \rightarrow A, D;$
  - $A, C \rightarrow B, C$
  - $A, C \rightarrow B, D$
  - $A, C \rightarrow B, C, D$
  - $A, D \rightarrow B, C, D$
  - $B, C \rightarrow B, D$

$A, C \rightarrow B;$! Ooops $A, C \rightarrow D$

$A, D \rightarrow B;$ $A, D \rightarrow C;$

$B, C \rightarrow D$

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Functional Dependencies

- Irreducibility: from last example
  - $A \rightarrow B, C$
  - $C \rightarrow D$
    1. $A \rightarrow B$
    2. $A \rightarrow C$
    3. $C \rightarrow D$
- The irreducible equivalent is ***NOT* unique**

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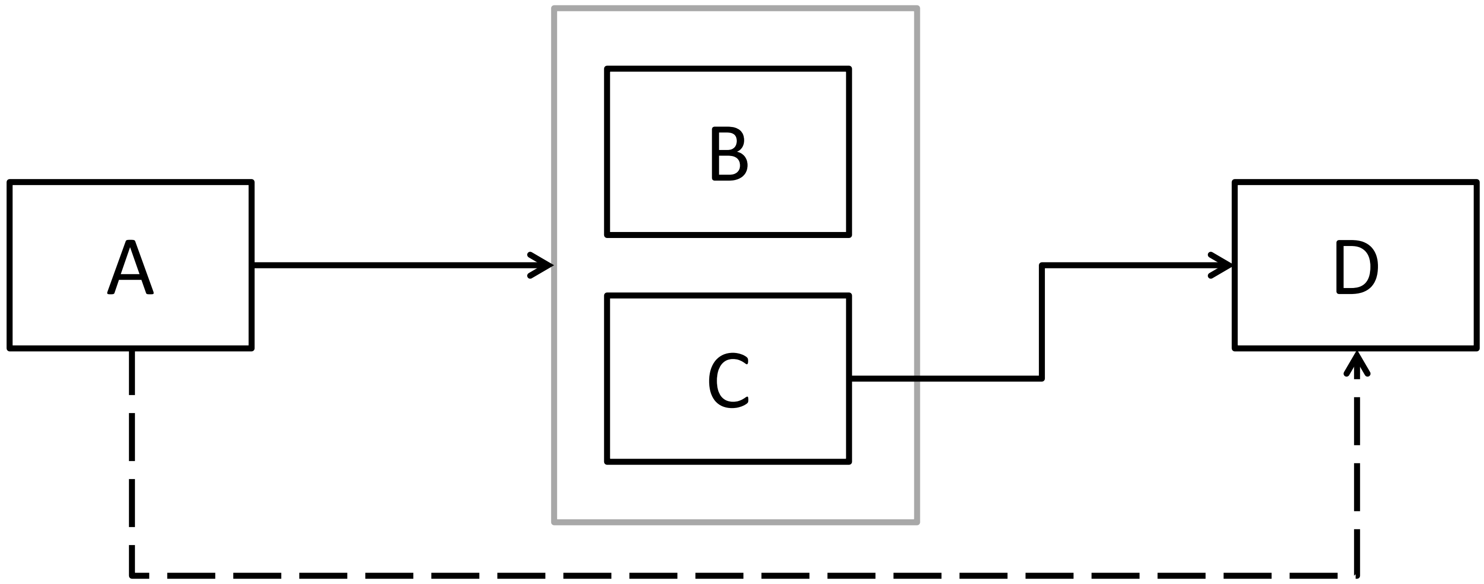
Functional Dependency Diagrams

- $\{A \rightarrow B, C; C \rightarrow D\}$



Normal Forms

- Example: Consider the our relation

ID#	Skill	M.St	#Chd	#Yrs	M.€	Date	#sticks	Wgt.	Hrs
1	Medium	M	0	2	40	1.06	55	9	6
2	Low	S	0	1	30	7.05	34	5	5
3	High	S	2	3	45	1.06	54	9	6
4	High	M	3	4	50	3.11	61	12	8

1st Normal Form (1NF)

- All legal relations are in 1NF

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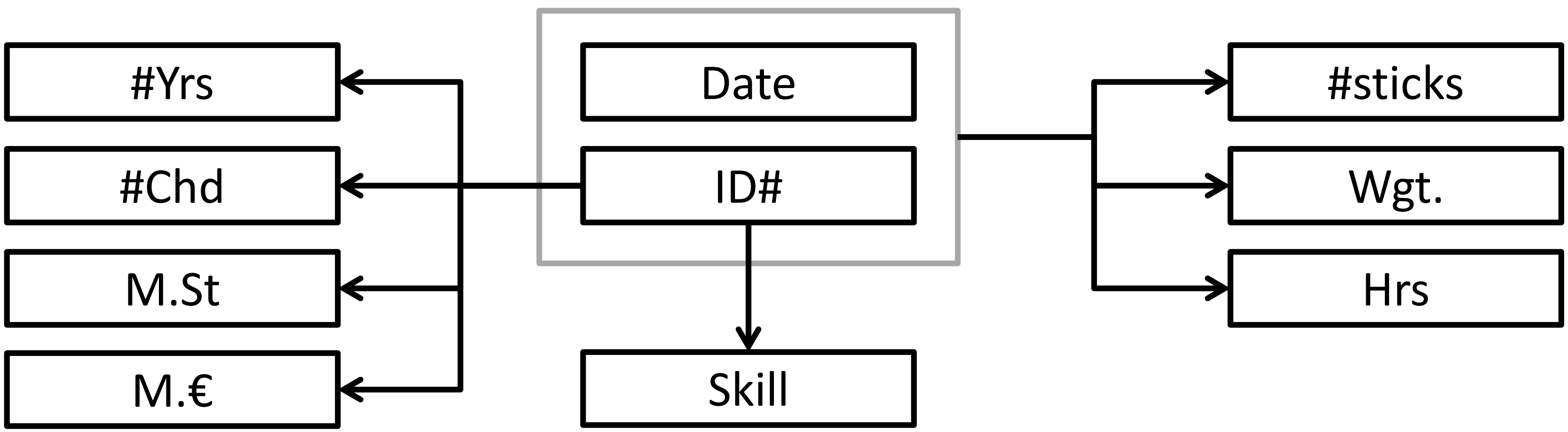
Normal Forms

- Some FDs in this relation?

ID#	Skill	M.St	#Chd	#Yrs	M.€	Date	#sticks	Wgt.	Hrs
1	Medium	M	0	2	40	1.06	55	9	6
2	Low	S	0	1	30	7.05	34	5	5
3	High	S	2	3	45	1.06	54	9	6
4	High	M	3	4	50	3.11	61	12	8



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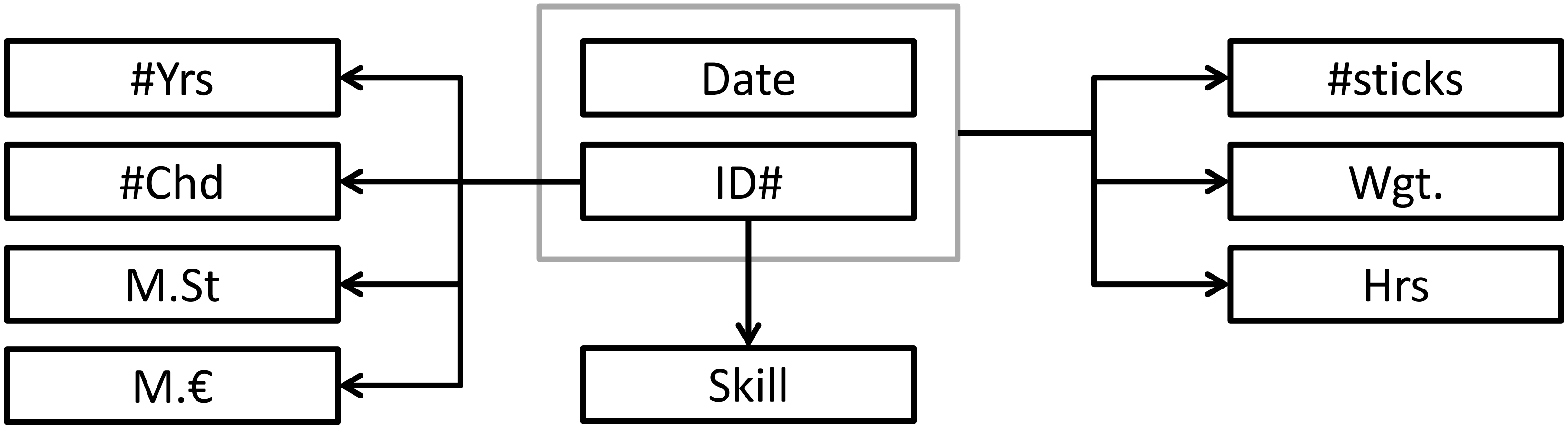
Normal Forms

- What are the problems with this relation?

ID#	Skill	M.St	#Chd	#Yrs	M.€	Date	#sticks	Wgt.	Hrs
1	Medium	M	0	2	40	1.06	55	9	6
2	Low	S	0	1	30	7.05	34	5	5
3	High	S	2	3	45	1.06	54	9	6
4	High	M	3	4	50	3.11	61	12	8



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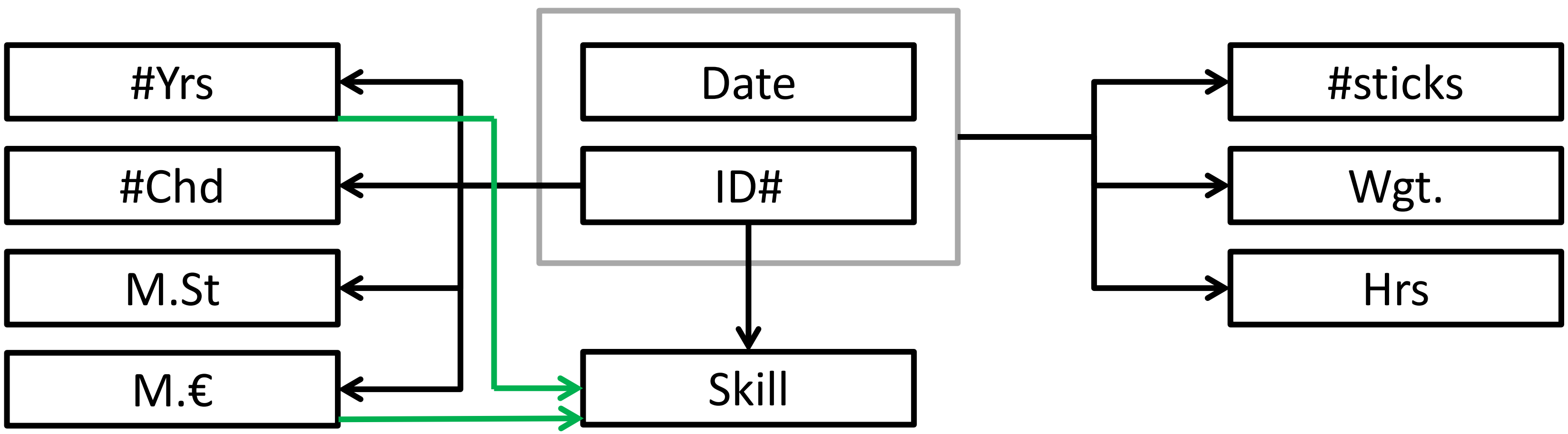
Normal Forms

- Let’s reveal a few more dependencies

ID#	Skill	M.St	#Chd	#Yrs	M.€	Date	#sticks	Wgt.	Hrs
1	Medium	M	0	2	40	1.06	55	9	6
2	Low	S	0	1	30	7.05	34	5	5
3	High	S	2	3	45	1.06	54	9	6
4	High	M	3	4	50	3.11	61	12	8



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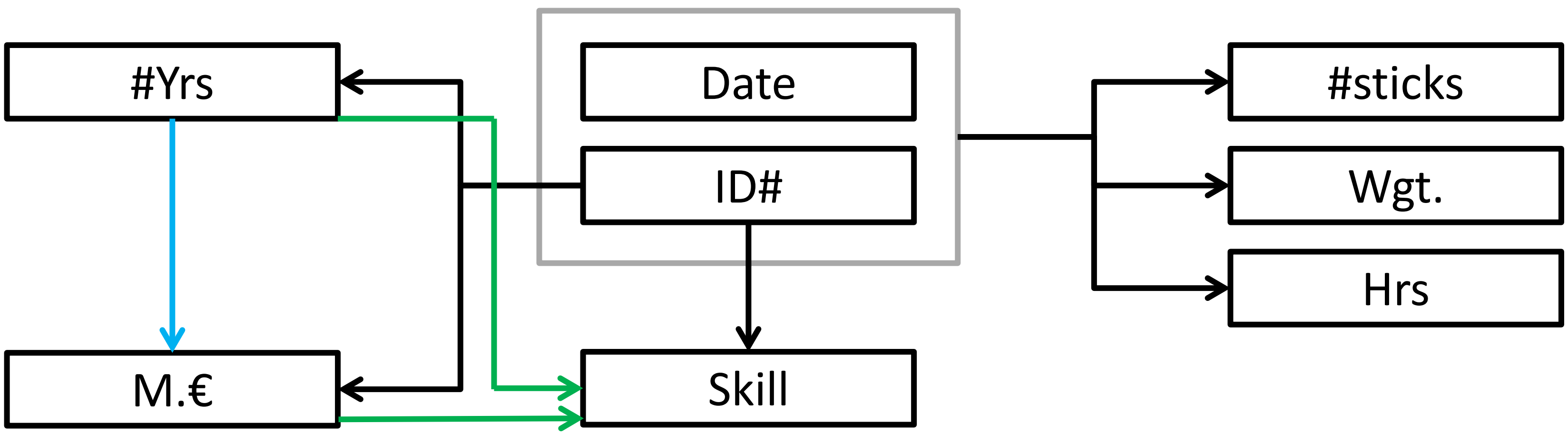
Normal Forms

- Let’s reveal a few more dependencies

ID#	Skill	M.St	#Chd	#Yrs	M.€	Date	#sticks	Wgt.	Hrs
1	Medium	M	0	2	40	1.06	55	9	6
2	Low	S	0	1	30	7.05	34	5	5
3	High	S	2	3	45	1.06	54	9	6
4	High	M	3	4	50	3.11	61	12	8

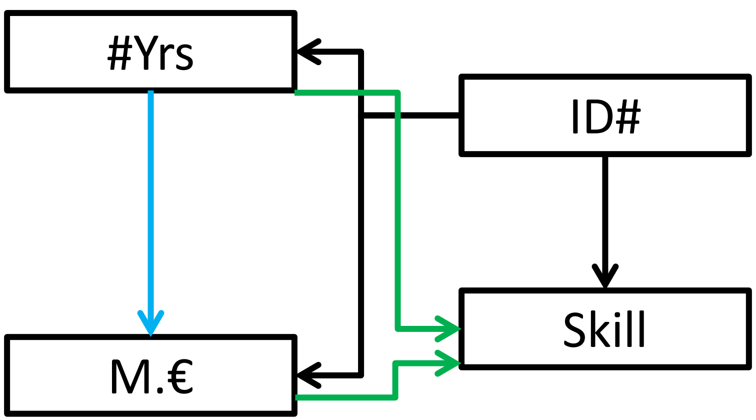


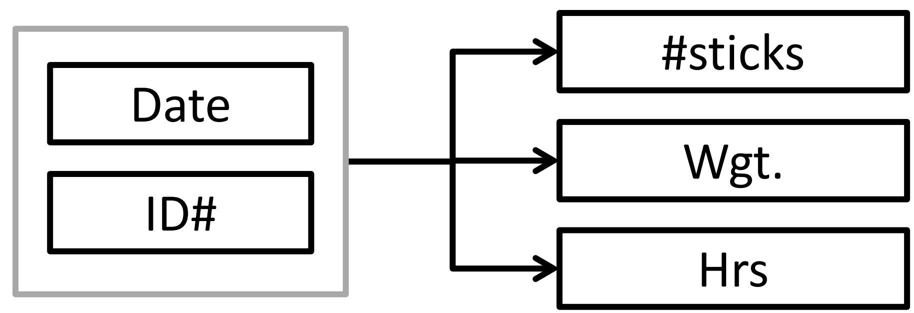
Normal Forms

- Decompose the relation by projecting it

ID#	Skill	#Yrs	M.€
1	Medium	2	40
2	Low	1	30
3	High	3	45
4	High	4	50

ID#	Date	#sticks	Wgt.	Hrs
1	1.06	55	9	6
2	7.05	34	5	5
3	1.06	54	9	6
4	3.11	61	12	8

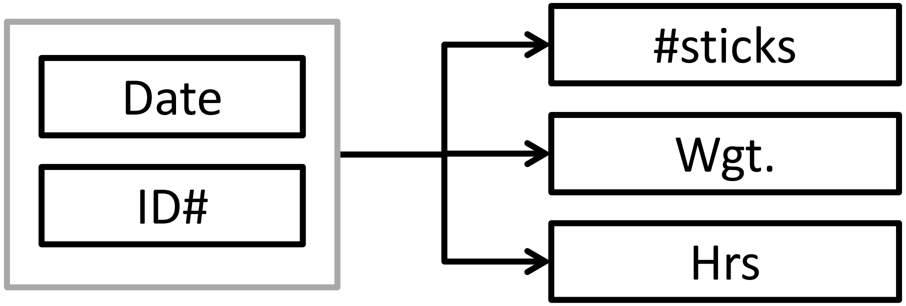




Normal Forms

- This relation is fine – It's at least in 2NF

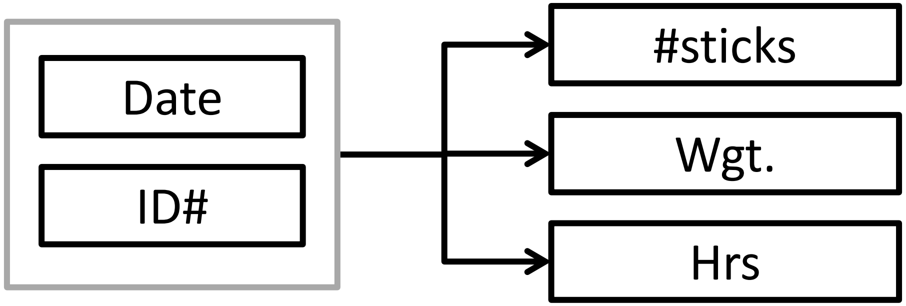
ID#	Date	#sticks	Wgt.	Hrs
1	1.06	55	9	6
2	7.05	34	5	5
3	1.06	54	9	6
4	3.11	61	12	8



Normal Forms

2nd Normal Form (2NF)

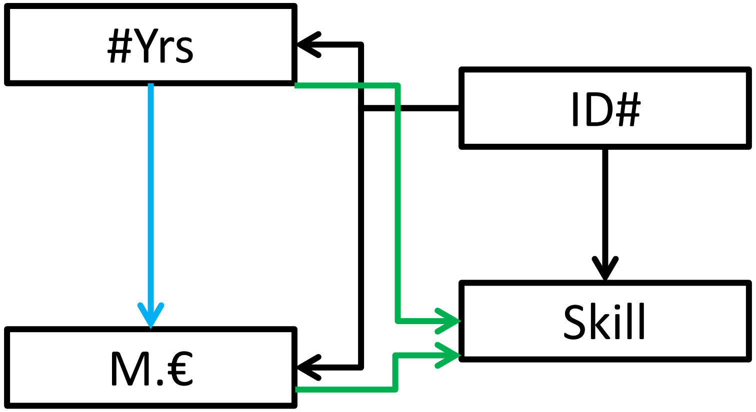
- A relation is in 2NF ***if and only if*** every nonkey attribute is ***irreducibly dependent*** on the Primary Key



Normal Forms

- What's wrong with this relation?

ID#	Skill	#Yrs	M.€
1	Medium	2	40
2	Low	1	30
3	High	3	45
4	High	4	50

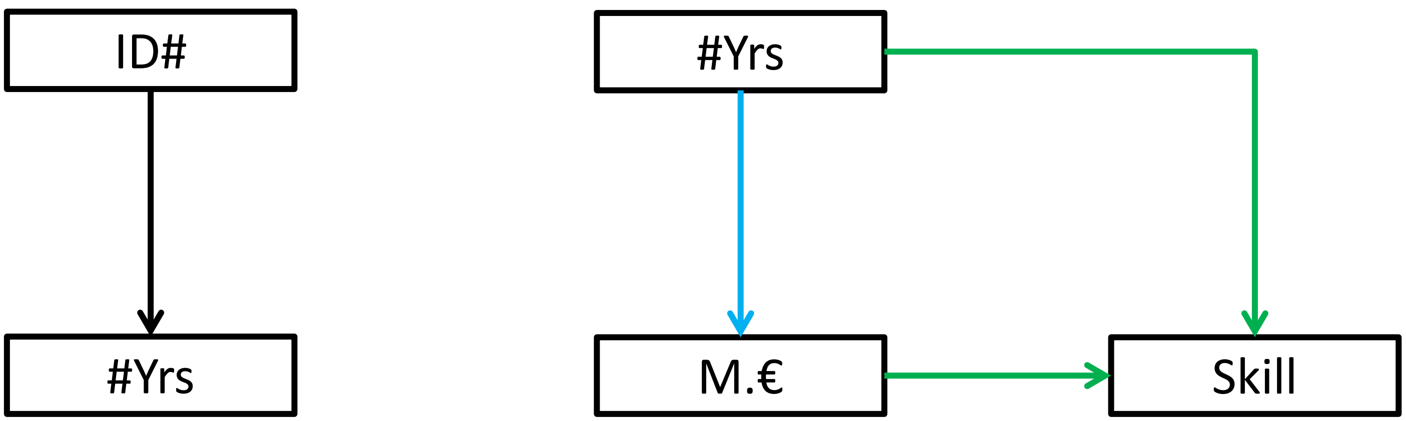


Normal Forms

- Decompose the relation – again by projection

ID#	#Yrs
1	2
2	1
3	2
4	4

#Yrs	Skill	M.€
2	Medium	40
1	Low	30
3	High	45
4	High	50



Normal Forms

3rd Normal Form (3NF)

- A relation is in 2NF ***if and only if*** it is in 2NF every nonkey attribute is ***nontransitively dependent*** on the Primary Key

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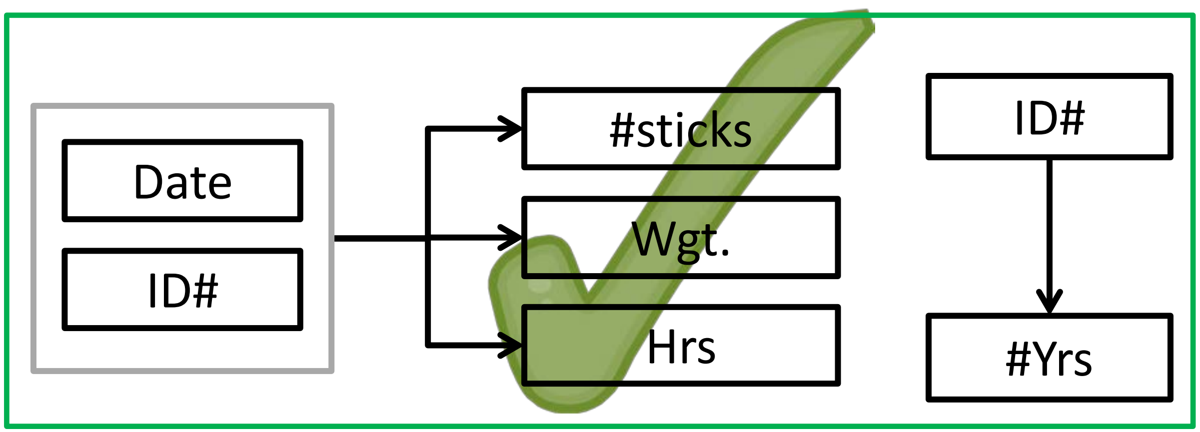
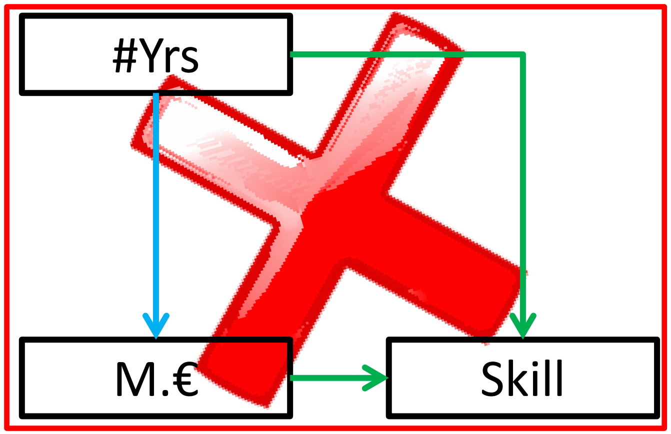
Normal Forms

3rd Normal Form (3NF)

- A relation is in 2NF ***if and only if*** it is in 2NF every nonkey attribute is ***nontransitively dependent*** on the Primary Key





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Normal Forms

- Decompose the relation – again by projection

#Yrs	M.€
2	40
1	30
3	45
4	50

#Yrs	Skill
2	Medium
1	Low
3	High
4	High

$$\boxed{\text{\#Yrs}} \rightarrow \boxed{\text{M.€}}$$

$$\boxed{\text{\#Yrs}} \rightarrow \boxed{\text{Skill}}$$

Boyce-Codd Normal Form

- Note in the previous examples we considered only a single candidate key
- Boyce-codd normal form considers also cases where we have overlapping candidate keys

Boyce-Codd Normal Form (BCNF)

- A relation is in BCNF ***if and only if*** every **nontrivial left irreducible** FD has a candidate key as its determinant (LHS)

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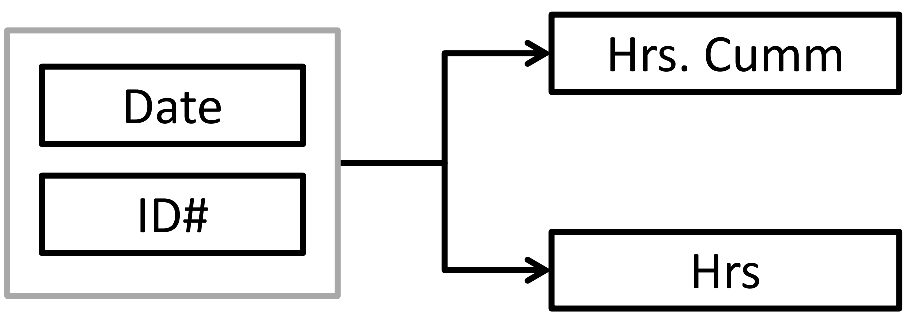
Boyce-Codd Normal Form

- In a diagram

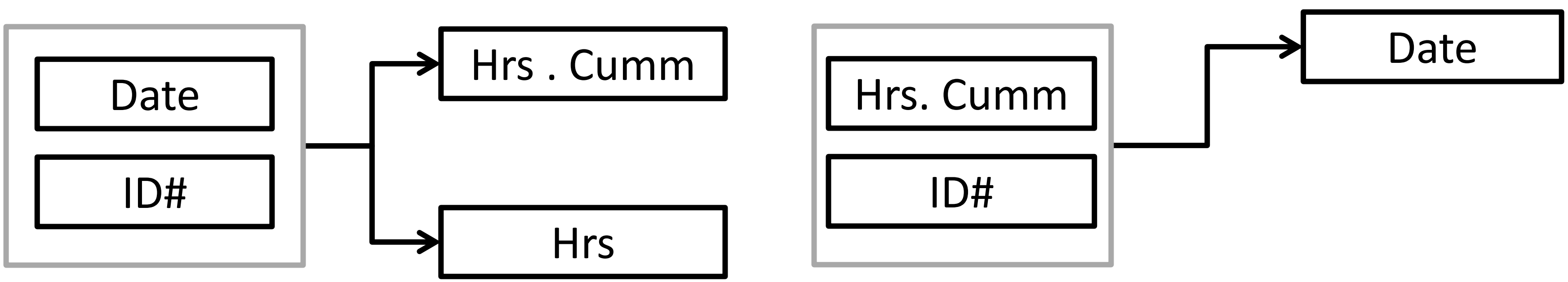
ID#	Date	#sticks	Wgt.	Hrs	Hrs. Cumm
1	1.06	55	9	6	2212
2	7.05	34	5	5	3182
3	1.06	54	9	6	3097
4	3.11	61	12	8	5220



Boyce-Codd Normal Form

- In a diagram

ID#	Date	#sticks	Wgt.	Hrs	Hrs. Cumm
1	1.06	55	9	6	2212
2	7.05	34	5	5	3182
3	1.06	54	9	6	3097
4	3.11	61	12	8	5220



References

- C.J. Date, *An Introduction to Database Systems, 8th Edition*. Pearson Education Inc., 2004.
- See www.geoinformatic.cc

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That's **NOT** all for today

Practical

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That’s all for today

Thank you!

Questions?

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