Data model

- A data model is a collection of concepts to define the structure and operations on data
  - All data models do not specify operations
- It has been found useful not to consider all aspects of data at the same time. - too many details
- Abstraction levels filter out the non-interesting aspects
- Three abstraction levels are typical in data modeling

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Abstraction levels

- **Conceptual level (**real word level):
  - The meaning of data
  - How things are related
  - What are the rules in the real world that should be respected in the database
  - Conceptual level data modeling is discussed in the Introduction to Application Analysis and Design – course

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Abstraction levels

- **Structural level (**logical level):
  - How the programmer or the direct user of the database sees the database
  - Structures of data
  - Operations on data
  - Different users may have different views of data
  - Programming languages may also have their own views of data

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Abstraction levels

- **Physical level:**
  - How is the data technically stored
  - What kind of files there are
  - Distribution
  - Structures to support fast retrieval of data (indexes)

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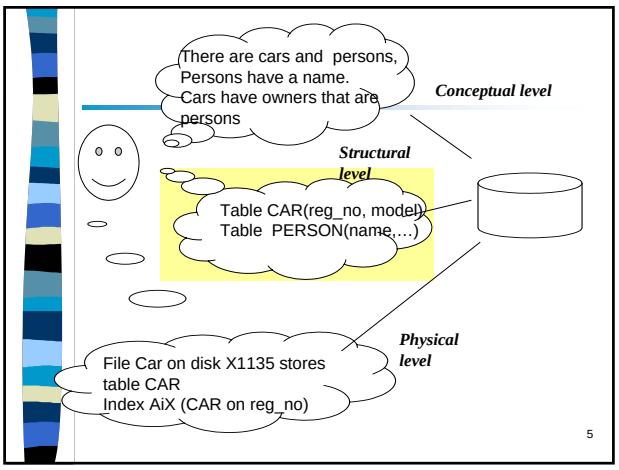

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Levels of abstraction and tasks using the levels

conceptual level	information analysis determination of contents
structural level	queries, programming
physical level	tuning, distribution

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Models in use

conceptual level
- Entity-Relationship models (ER)
- Object models
- Semantic data models

structural level
- **Relational model (current)**
- Object models (future?)
- Hierarchic model (ancient)
- Network model (ancient)

physical level
- Supplier dependent models

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Relational databases

- Origin: E.F.Codd: The relational model of data, ACM Communications, 1970
- First commercial implementations in the end of 70ies,
- Became popular by the end of 80ies
- Became dominant by the end of 90ies
- DB2, Oracle, Informix, Sybase, MS SQL Server, etc.

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The Relational Model of Data

- **The basis** :
- Database is considered as a collection of mathematical relations
- Few simple and well defined concepts
- Good theoretical basis
-
- Easy to comprehend using tabular representation

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Relation presented as a table

Attributes

Schema name

CAR	Reg_no	Color	Model
	ACM-256	black	1988
	MAC-532	blue	1994
	ISO-795	black	1992
	OSI-228	red	1987
	HCI-449	white	1993

Tuples

Value

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Relation presented as a table

column names

CAR	Reg_no	Color	Model
	ACM-256	black	1988
	MAC-532	blue	1994
	ISO-795	black	1992
	OSI-228	red	1987
	HCI-449	white	1993

rows

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Mathematical definition

- Let D_1, D_2, ..., D_n be sets of values (domains). They may overlap (have common values).
- Relation R is a set of tuples, the first value of which belongs to the first domain D_1, second to the second one D_2 , ,etc.
- Mathematically a relation is a subset of the Cartesian product $D_1 \times D_2 \times ... \times D_n$

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Tuple

- A tuple is a sequence of values (a1,…,an). In tabular presentation it is a row in a table.
- Cartesian product :
  - Cartesian product of sets A={1,2,3} and B={a,b} , denoted as A×B, is the set that contains all such pairs (binary tuples) (x,y) where the first value (x) belongs to set A and the second value (y) belongs to set B.
  - {(1,a), (1,b), (2,a), (2,b), (3.a), (3,b)}

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Domain

- A domain
  - Is a set of atomic values (value may not be broken down into pieces), for example,
    - integers
    - personal numbers
    - strings
  - Some operations presuppose that there is an order specified among the values of the domain
  - All values must be atomic – no sets or collections in one value position within a tuple
  - There is a special value NULL (meaning unknown or not valid) that belongs to **each** domain!

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Attribute = name of column

- Attribute is a name that identifies a value position in the tuples of a relation.
- Each attribute is associated with an **interpretation** that specifies the meaning of values in that position.
  - There may be many tuple positions holding integers but they all have different meanings
- Each attribute is connected to a domain of which the values are drawn.
- There is a value in each value position of a tuple.
- The domains should be defined so that their values cover all possible values needed in the corresponding position.
  - **For example, all colors**

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Relation schema

- The structure of a relation is specified in a **relation schema**
  - Names the attributes
  - Connects domains to attributes
  - Specifies the interpretations for attribute values
- Each relation schema has a name.

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Relation schema

- The most simple presentations of the schema (common in research articles and text books) gives the name of the schema and lists the attributes

  R(A1,…, Am),
- where R is the name of schema and A1,…,Am are attributes

  -This form of schema assumes that the attributes are descriptive enough to reveal the interpretation

  Example: Car(Reg_no,Color,ModelYear)

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Relation schema

- A more complete presentation identifies the value sets. Interpretations must be explained separately.

  Car*(Reg_no: Finnish_registration_numbers,*
  Color: Colorcodes,
  ModelYear: Integer >1900)
- A relation may be considered as a **instance** of the schema.
  - An instance portrays some phenomenon of the real world, for example, existence of cars in Finland on 1.1.2003. There is another instance of the same schema for some other date.

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Relation schema

- A relational database has only one instance of each relation schema at a time
- This instance is typically referred by the name of the schema.
- Relation Car = the current instance of schema Car

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Relation schema

- A relation is a **mathematical set**
  - Each value in a mathematical set is unique (occurs only once). Thus the tuples of a relation are unique.
  - A mathematical set is unordered.
- The order of attributes in a relation schema is not significant.

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Concepts

- Cardinality of a relation
  - Number of tuples (rows)
- Degree of a relation
  - Number of attributes
- Relational database
  - Collection of relations
- Relational database schema
  - Collection of the relation schemas that specify the relations of the database

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Theory - tabular presentation

Theory concept	Presentation concept
Relation	Table
Tuple	Row
Attribute	Column name

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Key

- The tuples in a relation are unique
  - A tuple may be uniquely identified by its contents
  - Usually we don't need the whole tuple for the identification, only some attribute values
- A key is an attribute (or attribute combination) that
  - has a unique value (or value combination) in each tuple of whatever instance of the relation schema
  - is minimal so that no attribute may be taken out of the combination and the remaining attributes still satisfy the above condition (I.e. identify tuples)

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Key

CAR

Reg_no	Color	ModelYear
ACM-256	black	1988
MAC-532	blue	1994
ISO-795	black	1992
OSI-228	red	1987
HCI-449	white	1993

•Reg_no and ModelYear, both alone, identify rows in this instance
•ModelYear would not anyhow identify rows in whatever valid instance – that would mean that there can be only one car for model year.

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Key

- An attribute that belongs to a key may not have null values
- Sometimes we may find out many keys for a relation schema
- One of these keys must be selected as a **primary key** (the primary way to refer to the tuples of this relation schema)
- Employee(personal_number,…, employee_number)
  - Both employee_number and personal_number are keys – we select as the primary key the one that suits better for the purpose. There are restrictions for the use of personal number, thus employee number is a better choice.

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Key

- The primary key is expressed in the relation schema by underlining its attributes

Car (RegNo, Color, ModelYear)
Employee (EmployeeNumber,…)
TennisCourtReservation (CourtID, StartingTime, Duration, PlayerName)

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Foreign key

- A database consists of many relations
- Typically there are connections between tuples of different relations
  - A tuple in Employee relation is connected to a tuple in Department relation indicating that the employee works on that department
  - A tuple in a library's Loan relation is connected to a tuple in relation Book and a tuple in relation Customer.
- In relational databases tuples are connected by including the primary key attribute values of the tuple to be connected into the tuple that establishes the connection.

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Foreign key

EMP	EmpNo		DeptNo
007			D01

must have same domain
need not have the same column name

DEPT	DeptID		DeptName
	D01		SPY Dept

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Foreign key

- An attribute or a combination of attributes that establishes a connection is called a **foreign key**.
- Connections are established using the values of the primary key attributes of the tuple to be connected as the values of the foreign key attributes.
- Null values may be allowed for foreign keys – then the tuples need not be connected to any other tuples

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Foreign key

EMP	EmpNo		DeptNo
007			D01

foreign key
reference

DEPT	DeptID		DeptName
	D01		SPY Dept

primary key

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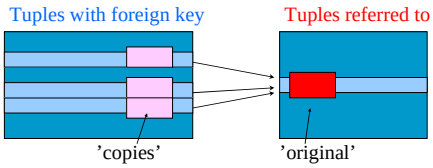
Foreign key

- Foreign key values are used in referring from one tuple to another. However the existence of the connection may be utilized also to the other direction
  - Which department is connected to a certain employee
  - Which employees are connected to a certain department



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Foreign key

- In this course we show the foreign keys in a relation schema using an arrow in the following way

  Ownership(PersonID →Person, CarID→Car)
  - PersonID refers to Person, CarID refers to Car
  - In this relation the foreign keys are part of the primary key. Thus they may not have null values.
  - Foreign keys may be outside the primary keys.
  - Then they may or may not have null values

  EMP(EmpNo, …, DeptNo→DEPT)
  - DeptNo refers to a tuple of DEPT

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Foreign key

Participant(Who→Student,
(CourseID,GroupNumber)→ExerciseGroup)

- The foreign key that refers to ExerciseGroup consists of two attributes. This indicates that the primary key of ExerciseGroup also consists of two attributes.

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Foreign key

- Foreign keys may also be used in connecting tuples of the same relation.
- Employee(EmpNo, …,Boss → Employee)
  - attribute Boss has as its value the EmpNo value of some other employee.

Employee	EmpNo		Boss
	001		NULL
	005		001
	007		001

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Foreign key

- Referential integrity:
  - It is not allowed to refer to non-existing tuples, i.e. the foreign keys may have as their values only values that exist as primary key values in their own relation.
  - If NULL is used as the foreign key value the tuple is not connected to anything.

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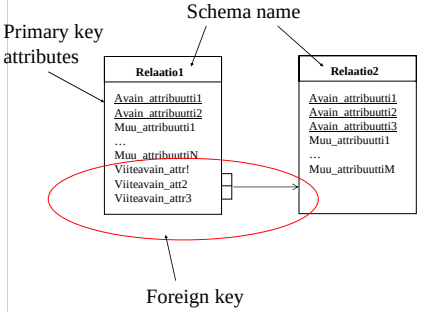
Foreign keys –graphical representation



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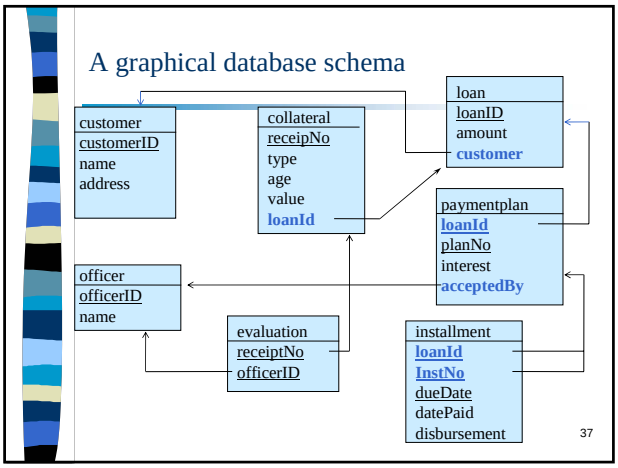
A graphical database schema
customer
customerID
name
address
collateral
receipNo
type
age
value
loanId
loan
loanID
amount
customer
paymentplan
loanId
planNo
interest
acceptedBy
officer
officerID
name
evaluation
receiptNo
officerID
installment
loanId
InstNo
dueDate
datePaid
disbursement
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