

Informatics 1: Data & Analysis

Lecture 3: The Relational Model

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Data Representation

This first course section starts by presenting two common **data representation models**.

- The *entity-relationship (ER)* model
- The *relational* model

Data Manipulation

This is followed by some methods for manipulating data in the relational model and using it to extract information.

- *Relational algebra*
- The *tuple-relational calculus*
- The query language *SQL*

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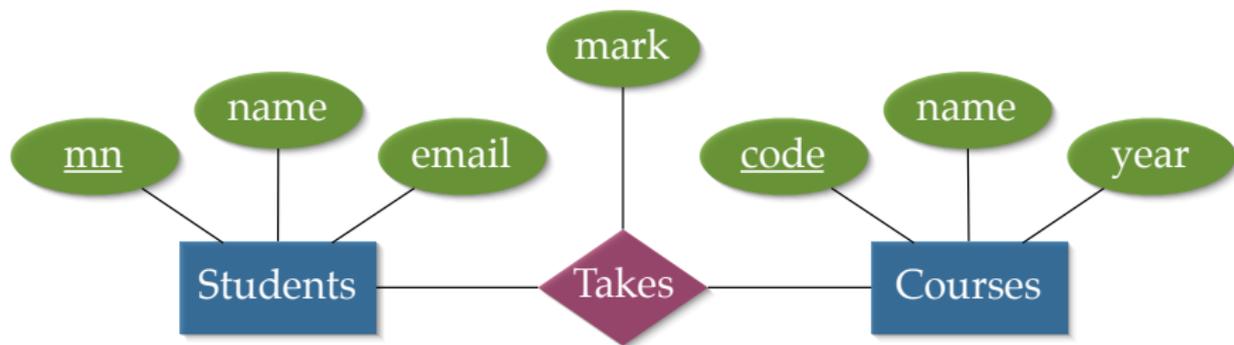
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Entity-Relationship Modelling

The Story so Far

- Requirements Analysis; **Conceptual Design**; Logical Design
- Entities, Entity Sets, Entity Instances
- Attributes, Domains
- Keys: Candidate Keys, Primary Keys, Composite Keys
- Relationships, Relationship Sets, Relationship Instances



Classifying Relationships

A binary relationship set R between entity sets A and B can be:

Many-to-one: Each entity x of A may appear in at most one relationship instance (x, y) from R .

One-to-many: Each entity y of B may appear in at most one relationship instance (x, y) from R .

Many-to-many: No limits on the number of relationship instances any particular entity may appear in.

Examples?

email **from** sender; street **contains** house; student **takes** course.

Key Constraints

We can extend the idea of **many-to-one** beyond binary relationships.

An entity set E has a *key constraint* in relationship R if each entity instance x of E can appear in at most one relationship instance (x, y, z, \dots) from R .

An ER diagram indicates a key constraint with an arrowhead on the line joining entity set E to relationship set R .

Note

There is a subtlety here: a key constraint does not just report that entity instances happen to appear in no more than one relationship — instead, it asserts a structural property of the data that each entity instance **cannot** be in more than one relationship.

Participation Constraints

Total Participation of entity set E in relationship set R means that every entity x in E appears in at least one relationship instance from R.

Partial Participation of entity E in relationship R means that some entity instances in E might appear in no relationship instance from R.

Examples?

student **speaks** language; country **uses** currency; person **has** email account

ER diagrams indicate total participation with a thick or double line from the entity to the relationship.

Again this indicates not just happenstance but a structural constraint on the data model: each entity instance **must** appear in the relationship.

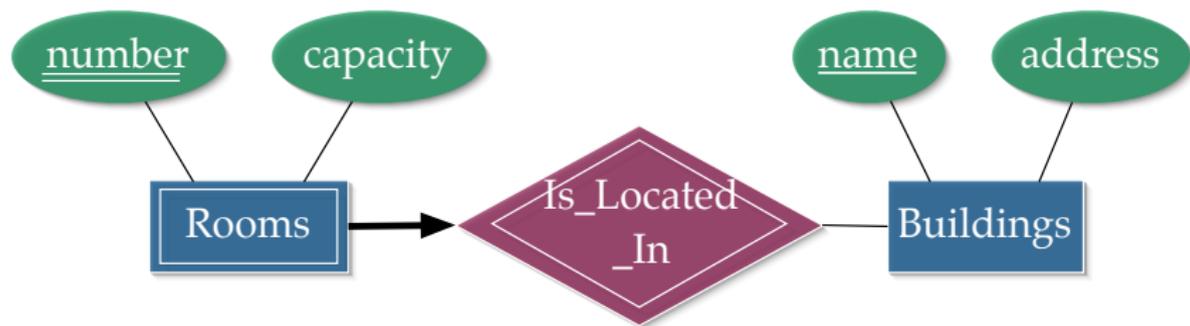
Weak Entity Sets

Sometimes the attributes of an entity are not enough to build a key which uniquely identifies each individual.

We may be able to fix this using attributes from other, related, entities.

This can only work if the entity set has a **key constraint** and **total participation** in the *identifying relationship*.

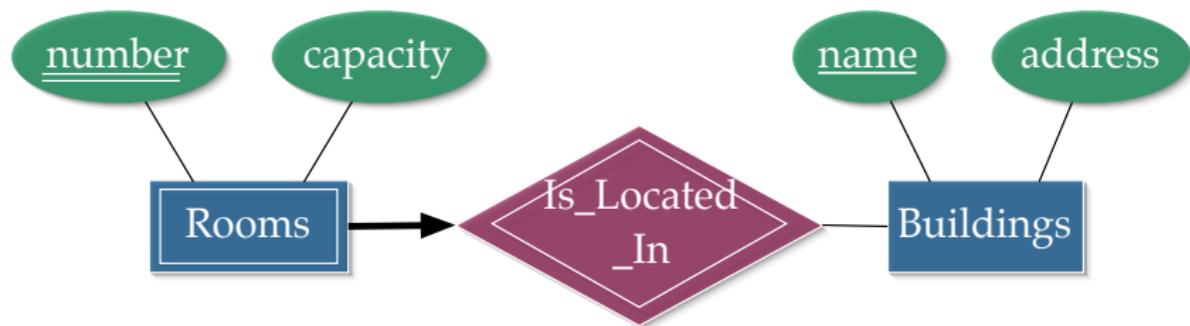
This is then a *weak entity set*, with borrowed attributes coming from the uniquely-defined *identifying owner*.



Weak Entity Sets

ER diagrams represent *weak entity sets* by:

- A double or thick border on the rectangle of the weak entity set;
- A double or thick border on the diamond of the identifying relationship;
- A double or thick line and arrow linking these;
- A double or dashed underline for the attributes of the weak entity set that contribute to the composite key.

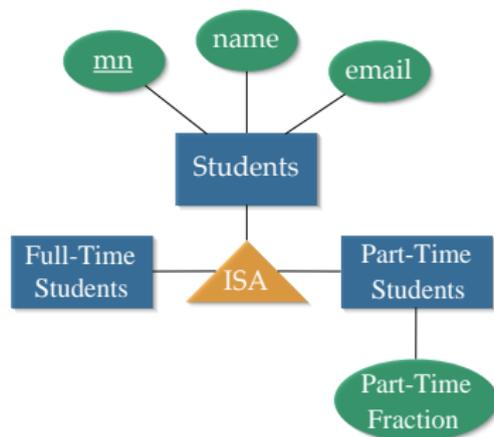


Entity Hierarchies and Inheritance

Sometimes one or more kinds of entity will refine another: a *subclass* entity *specializes* a *superclass* entity.

Each subclass entity *inherits* the attributes of the superclass entity, and may add its own attributes too.

ER diagrams represent inheritance with an *IS-A* triangle.



Entity-Relationship Refinements

What We've Just Seen

- One-to-Many relationships, Many-to-One, Many-to-Many
- Key constraints
- Participation constraints, Total participation, Partial participation
- Weak entities, Identifying relationship, Identifying owner
- Entity hierarchies, Inheritance

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But why?

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Whitehead: Civilization advances by extending the number of important operations which we can perform without thinking about them.

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Whitehead: Civilization advances by extending the number of important operations which we can perform without thinking about them.

Operations of thought are like cavalry charges in a battle — they are strictly limited in number, they require fresh horses, and must only be made at decisive moments.

Introduction to Mathematics, 1911

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Tutorials

The course web page now links to lists of tutorial group membership, places, times and tutors. The first exercise sheet will be online later today.

Please check which tutorial group you are in, when and where it meets. If you wish to move to a different group then ask the ITO through their online contact form: <http://www.inf.ed.ac.uk/teaching/contact>

Homework

Before the next lecture, on Friday, read the remaining sections, §§2.5 onwards, of Ramakrishnan and Gehrke, completing Chapter 2.

These consider trade-offs and choices in the design of Entity-Relationship models, as well as more on the wider context of modelling.

History of the Relational Model

The *relational model* was introduced in 1970 by Edgar F. Codd, a British computer scientist working for IBM in California.

A key insight, and a reason for the success of the relational model, is its separation between *specification* (what you want to find out) and *implementation* (how the system should find it out for you).

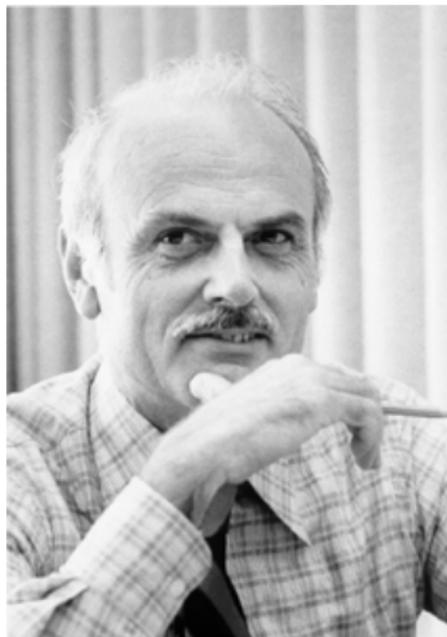
IBM were initially reluctant to exploit Codd's idea, but did in due course develop the *System R* database platform which led the commercial development of *relational database management systems* (RDBMS).

System R included the SEQUEL language, which then became SQL and the standard query language for all subsequent relational databases.

Relational database management systems are now a very large industry: G\$36 market size in 2011, and growing.

Codd received the [1981 Turing Award](#) for his work on databases.

Codd



Credits: IBM, Ferkel

Building Blocks

Relational databases take as fundamental the idea of a *relation*, comprising a *schema* and an *instance*.

- The **schema** is the format of the relation:
 - A set of named *fields* (or *attributes* or *columns*)
 - For each field its *domain* (or *type*)
- The **instance** of a relation is a *table*:
 - A set of *rows* (or *records* or *tuples*)
 - Each row gives a value for every field, from the appropriate domain.
- The *arity* of a relation is the number of fields in its schema.
- The *cardinality* of a relation is the number of rows in its table.

Everything in a relational database is built from relations and operations upon them.

Example

Fields (a.k.a. attributes, columns)

Schema →

mn	name	age	email
s0456782	John	18	john@inf
s0412375	Mary	18	mary@inf
s0378435	Helen	20	helen@phys
s0189034	Peter	22	peter@math

Tuples
(a.k.a. records,
rows)

Every relational database is a linked collection of several tables like this: often much wider, and sometimes very, very much longer.

SQL: Structure Query Language

- SQL is the standard language for interacting with relational database management systems
- Substantial parts of SQL are **declarative**: code states what should be done, not necessarily how to do it.
- When actually querying a large database, database systems take advantage of this to plan, rearrange, and optimize the execution of queries.
- Procedural parts of SQL do contain **imperative** code to make changes to the database.
- While SQL is an international standard (ISO 9075), individual implementations have notable idiosyncrasies, and code may not be entirely portable.

DDL: SQL Data Definition Language

The *Data Definition Language* is a portion of SQL used to declare the schemas for relations.

In particular the DDL contains the imperative command **CREATE TABLE** which sets up a fresh, empty, table with a certain schema.

For simplicity, we'll use schemas with only three types:

- **INTEGER** for integer values;
- **FLOAT** for floating point real-valued numbers;
- **VARCHAR(n)** for strings of length up to *n*.

It's conventional, although not at all universal, to write SQL keywords in UPPER CASE, with lower or Mixed Case for identifiers. This isn't enforced by the language.

There are some moderately complex rules about use of quotation marks around identifiers and strings, which I'll talk about some other time.

DDL Example

```
CREATE TABLE students (  
    matric VARCHAR(8),  
    name VARCHAR(20),  
    age    INTEGER,  
    email VARCHAR(25),  
    PRIMARY KEY (matric) )
```

The general form of this statement is

```
CREATE TABLE table-name (  
    attribute-name attribute-type  
    [ , attribute-type attribute-type ]*  
    <integrity constraints> )
```

DDL Example

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CREATE TABLE students (  
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    PRIMARY KEY (matric) )
```

The final line declares a *primary key constraint*, that `matric` is the primary key for the `students` table.

This states that no two rows in the `students` table can share the same value for `matric`.

The constraint is enforced by the system: any attempt to insert a new row that duplicates an existing `matric` value will fail.

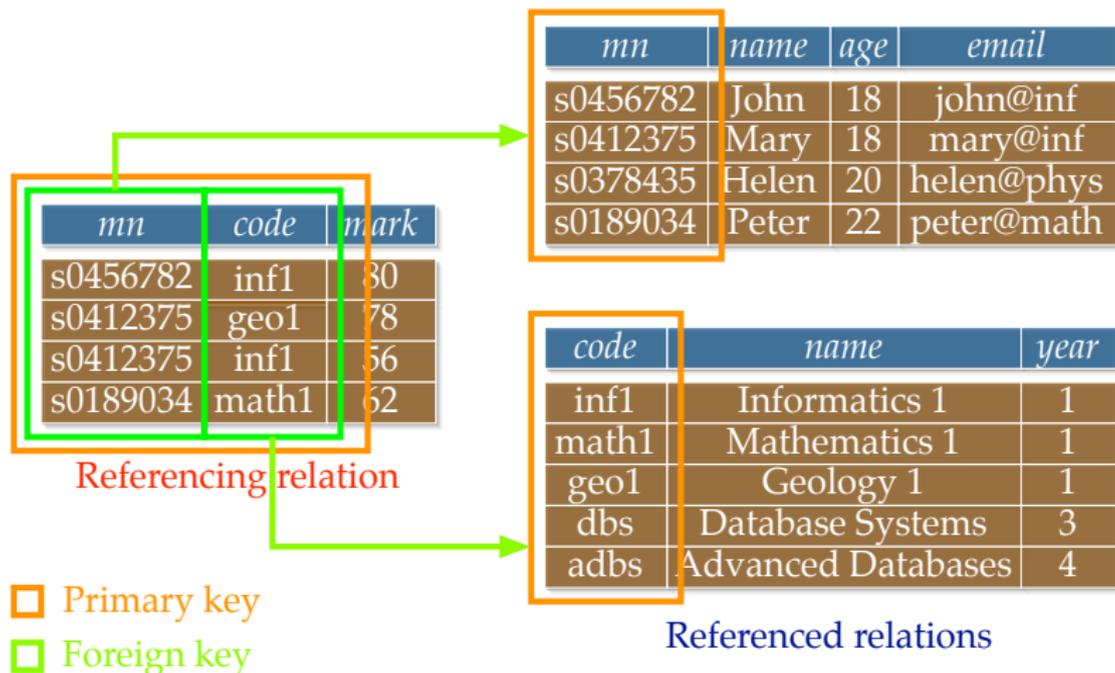
DDL Example

```
CREATE TABLE takes (  
    matric VARCHAR(8),  
    code  VARCHAR(20),  
    mark  INTEGER,  
    PRIMARY KEY (matric, code),  
    FOREIGN KEY (matric) REFERENCES students,  
    FOREIGN KEY (code) REFERENCES courses )
```

Here additional *foreign key constraints* declare that `matric` will always take a value which appears in the `students` table, and `code` will always be from the `courses` table.

These constraints are also enforced by the system, and no rows can be added that do not satisfy all of them.

Constraints from DDL



From ER to Relational Models

Entity-relationship modelling gives a high-level conceptual design for a database system, showing what things are to be recorded and how they are connected.

The relational model supports a more explicit logical design, closer to implementation.

Some work is required to move between them: notice, for example, that in the ER model **students** would have been an entity with attributes, and **takes** a relationship between entities, in the relational model both are implemented as tables.

In the next lecture we shall look at how to systematically transform an ER model into a relational one.