Software systems

Xin Wang

I. Overview

A. Analysing software systems

- Aspects to consider:
  - System high-level functions
  - System nodes
  - Types of data managed and processed
  - Data movement within the system
- Usually expressed with pictures

B. Modelling data (Database)

- Data is always stored, transformed and analysed
- **Abstract Data Model** used to understand process
- **Database theory** creates the Abstract Data Model
- Database theory considers:
  - Important entities in Database
  - **Attributes** of these entities
  - **Relationships** between these entities
- **Entity modelling** formally expresses database theory
- **Database systems** implements the Abstract Data Model

C. Moving data (Network)

- Process of data moving between nodes
- **Network models** defines the type of network structure
- **Network protocol** and **API** implements the model

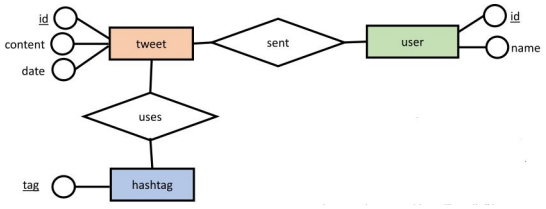
II. Entity Relation Modelling

- Creates **Entity Relationship Diagram**
- Establishing **relationships** in a given system:
  - **Entities**: Aspects within a given system
  - **Relationships**: How entities are related
  - **Attributes**: Properties of an entity or relationship
- Captures constraints and requirements on data
- Used as a guide to *implement* relations

Entity Sets	A set of distinguishable entities that all have the same set of properties (attributes). Could be physical things, events, conceptual, ... Normally correspond to nouns	Rectangle Student
Relationship	A relationship set describes how two or more entity sets are related to each other. Some times correspond to verbs : *owns, has, drives, ...* Entity sets can be involved in many relationship sets	Diamond manages
Attributes	Properties or attributes of an entity or relationship set. Underlined attributes are ***primary keys***.	Small circles id name

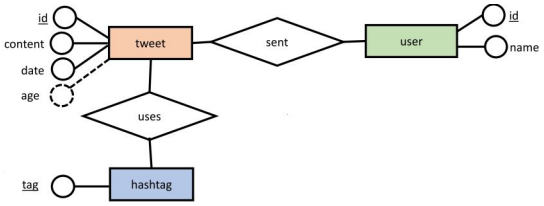
A. Primary keys

- An attribute that **uniquely identifies** an entity
- Properties:
  - There will never be two entities with the same key
  - Can contain **multiple** attributes if needed
  - Shown on ERD as underlined attributes
- Two types of primary keys:
  - **Natural keys**: Attributes from application data
  - **Surrogate keys**: *Invented* attributes

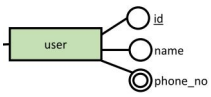


B. Complex attributes

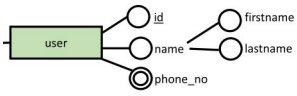
- **Computed attributes**: Calculated from other attributes



- **Multi-valued attributes**: Sets or lists of multiple values

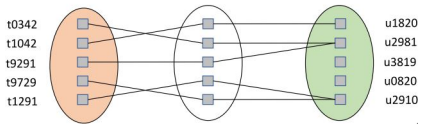


- **Composite attributes**: Properties that has sub-attributes



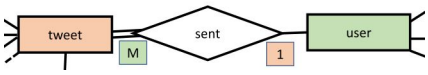
III. Relationships: Sets of relations

- Entity sets contain distinct entities
- **Relationships** contain sets of relations
- Each **relation** is a *pair of links* to an entity in the two entity sets

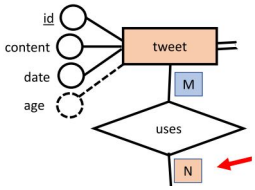


A. Relation constraints

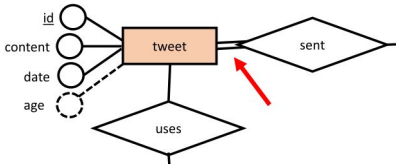
- **Cardinality constraint**: Number of times entity appears
  - One-to-one
  - One-to-many



  - Many-to-many

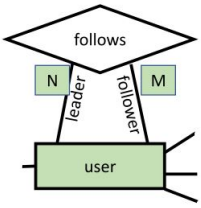


- **Total participation**: Entities **must** appear in relationships



B. Self relations

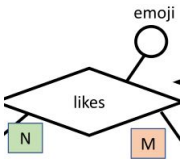
- Label the two connecting lines to show **roles**



- Cardinality constraints still apply

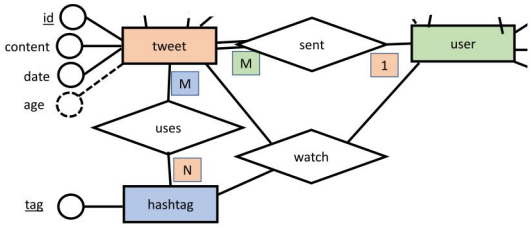
C. Relations with attributes

- Example: User can like a tweet with emojis



D. Three-way relationships

- Some relationships have more than two entity sets
- Example: User can *watch* for new retweets



IV. ERM and Relations

- Entities can be mapped into relations i.e. ERM
- ERM captures important aspects of the world
- With an ERM, work can be done on data e.g. SQL

A. Relations

ATTRIBUTES (the columns)
name:type

HEADING

BODY

title:string	year:int	length:int	genre:string
Gone with the Wind	1939	231	Drama
Star Wars	1977	124	SF
Wayne's World	1992	95	Comedy

TUPLES (the rows)

- Relation composition:
  - Relation Name
  - Heading:
    - Attributes:
      - Name
      - Type
  - Body:
    - Tuples
      - Attribute value i.e. name and value
- **Database**: Collection of relations
- **Relation Schema**: Relation name + Header
  - *movies(title:string, year:int, length:int, genre:string)*
- **Database Schema**: Collection of relation schema

B. ER diagrams → Relations → SQL

- Turning ER diagrams into concrete relations:
  - ER attributes → Relation attributes
  - ER entity → Relations
  - ER relationship sets → Relations or may disappear
- Relations are then turned into SQL

V. Structure Query Language (SQL) Introduction

- Domain specific language
- Defines, query and updates data
- Mostly portable and often performance tuning required
- Composed of **tokens**:
  - **Keywords**: CREATE, TABLE, SELECT ...etc
  - **Ordinary identifier**: *x*, *y*, *movies*
  - **Numbers**:3, 4.1, 1e-9
  - **Delimited identifiers**: "Peter, Mary"
- SQL are case-sensitive

A. Creating a table

```
CREATE TABLE movies (
    title varchar(100),
    year int,
    length int,
    genre char(16)
);
```

title:string	year:int	length:int	genre:string
Gone with the Wind	1939	231	Drama

B. Inserting data into a table

```
INSERT INTO movies
    VALUES (
    "Gone with the Wind",
    1939,
    231,
    "Drama"
);
```

title:string	year:int	length:int	genre:string
Gone with the Wind	1939	231	Drama

C. Extracting data from table

```
SELECT * from movies;
sqlite> select * from movies;

Gone with the Wind|1939|231|Drama
Star Wars|1977|124|SF
Wayne's World|1992|95|Comedy
```

title:string	year:int	length:int	genre:string
Gone with the Wind	1939	231	Drama
Star Wars	1977	124	SF
Wayne's World	1992	95	Comedy

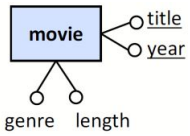
D. Extracting data from a table with filter

```
SELECT * from movies WHERE year = 1977;

Star Wars|1977|124|SF
```

VI. Mapping ERM to Relations

A. Entities and attributes

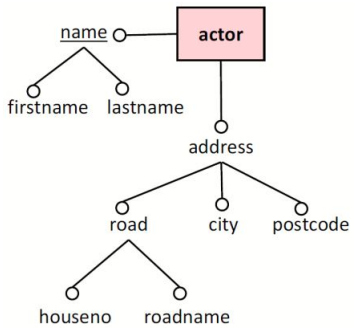
- Simple attributes:
  - Entity maps to relation with same attributes
  - Each entity in set becomes a row in relation
  - Entity primary key is relation primary key



movie(title, year, length, genre)

```
create table movie (
    title    varchar(120),
    year     int,
    length   int,
    genre    char(20),

    primary key (title, year)
)
```

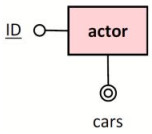
- Composite attributes:
  - Composite attributes become list of attributes



actor(firstname, lastname, houseno, roadname, city, postcode)

```
create table actor (
    firstname    varchar(30),
    lastname     varchar(30),
    houseno      int,
    roadname     varchar(30),
    city         varchar(40),
    postcode     varchar(10)

    primary key (firstname, lastname)

)
```

- Multi-valued attributes:
  - Attributes become own relation
  - Relation linked to original set with **foreign key**



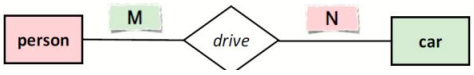
actor(ID, *otherattributes*)
actor_cars(actorID, carID, *otherattributes*)

```
create table actor_cars (
    actorID   int,
    carID     varchar(10),

    primary key (actorID, carID),
    foreign key (actorID) references actor.ID
)
```

- Derived attributes:
  - Not directly supported
  - Can be defined and used **within queries**

B. Relationship sets

- Many-to-many relationship:
  - Relation with two foreign keys
  - Entity primary key is relation primary key



person(ID, *otherattributes*)
car(regno, *otherattributes*)
drive(personID, regno,*otherattributes*)

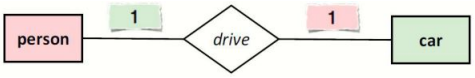
```
create table drive (
    personID  varchar(10),
    regno     varchar(12),
    primary key (personID, regno),
    foreign key (personID) references person.ID on delete cascade,
    foreign key (regno) references car.regno on delete cascade

)
```

- One-to-many relationship:
  - Primary key of one as foreign key in another

person(ID, *otherattributes*)
car(regno, personID, *otherattributes*)

```
create table car (
    regno     varchar(12),
    personID varchar(10),
    primary key (regno),
    foreign key (personID) references person.ID
)
```

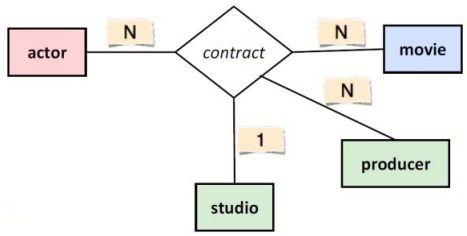
- One-to-one relationship:
  - Primary key of one as foreign key in another



person(ID, regno, *otherattributes*)
car(regno, *otherattributes*)

```
create table person (
    personID  varchar(12),
    regno     varchar(10),
    primary key (personID),
    foreign key (regno) references car.regno
)
```

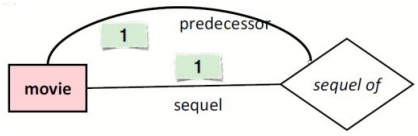
- Multi-way relationship:
  - Form relation with foreign keys to entity sets
  - Entity foreign keys form relation primary key



actor(ID, *otherattributes*)
movie(ID, *otherattributes*)
studio(ID, *otherattributes*)
producer(ID, *otherattributes*)
contract(aID, mID, sID, pID,*otherattrs*)

```
create table contract (
    actorID int, movieID int, studioID int, producerID int,
    primary key (actorID, movieID, producerID),
    plus foreign key declarations for actorID, movieID, studioID, producerID
)
```

- One-way relationship:
  - Each role is foreign key on entity set



movie(ID, *otherattributes*)
sequelof(originalID, sequelID, *otherattributes*)

```
create table sequelof (
    originalID int,
    sequelID int,
    primary key (originalID, sequelID),
    foreign key originalID references movie.ID,
    foreign key sequelID references movie.ID
)
```

VII. Networks intro

- **Information**: Transmissible signal to receiver
- **Data**: Information in machine-encoded form
- **Network**: Graph of nodes and channels:
  - **Channel**: Path over which signals flow
  - **Node**: Device within network sending/receiving data
- Network metrics:
  - Bandwidth: Throughout of many bytes
  - Latency: Delivery time for one byte
  - Jitter: Variation in latency
  - Loss: Proportion of bytes lost

VIII. Types of networks

- Network switching: How network is implemented
  - Circuit switching
  - Packet switching
- Network connection service: What network offers to users
  - Connectionless
  - Connection orientated

A. Network switching

- Circuit switching:
  - Circuit maintained for duration of use
  - Three stages:
    - Circuit establishment i.e. route established
    - Data transfer
    - Circuit disconnection
  - Only overheads are set-up costs
  - Constant costs per unit time even if not in use
  - If any link/switch breaks, entire circuit breaks
- Packet switching:
  - Data sent as small packets of bits
  - Each packet routed independently
    - Each packet must contain routing information
  - Packets may arrive out of order or get lost
  - Cost charged for each packet sent through

	Circuit switched	Packet switched
Bandwidth	Fixed	Variable
Setup overhead	Yes	No
Cost per data	No	Yes
Cost per time	Yes	No
Delivery order	In-order	Out-of-order
Node or channel failure	Circuit fails	Packets re-routed(some lost)

B. Types of connection service

- Connectionless service:
  - No route is maintained
  - Data is transmitted as packets
  - Packets may be re-ordered
  - No setups initially
  - Similar to Packet Switching
- Connection-orientated service:
  - Route is maintained
  - Data transmitted as bytes along connection
  - Data arrives in the same order it was sent
  - Route established before data can be sent
  - Similar to Circuit Switching

C. Virtual Circuit Switching

- Packeted-switching and Connection-orientated preferred
  - Packet-switching: Robust routing, efficient sharing
  - Connection-orientated: Reliable and in-order sending
- Virtual circuit provide connection using packets
  - Virtual circuit setup over packet-switched network
  - Each node remembers virtual route
  - Data sent as packets along virtual connection
  - Packet are routed on established virtual route

D. Quality of Service

- **Quality of Service** (QoS) guarantees:
  - Bandwidth: Minimum bandwidth along route
  - Latency: Maximum latency along route
- Circuit-switched: Worst channel in route
  - Determined when route is established
- Packet-switched: QoS very difficult to guarantee
  - Bandwidth varies according to demand
  - Latency varies according to channel congestion
- Virtual circuit: QoS with **partial resource allocation**