Golang Programming

Working with SQL Databases in Go

Where to Find The Code and Materials?

https://github.com/iproduct/coursego

Introduction to Databases and Distributed Data Processing

Databases, DBMSs and DB Models

- Database - an organized collection of data, generally stored and accessed electronically from a computer system. Can be developed using formal design and modeling techniques.
- DataBase Management System (DBMS) – software that interacts with end users, applications, and the database to capture and analyze the data, providing core facilities to create and administer databases.
- DBMSs can be classified according to the database models that they support:
  - In 1980s relational databases became dominant, modelling data as rows and columns in a series of tables, and the vast majority use Structured Query Language (SQL) for writing and querying data.
  - In the 2000s, non-relational databases became popular, referred to as NoSQL because they use different query languages.

Relational Databases

- "Relational database" term – invented by E. F. Codd at IBM in 1970, paper: "A Relational Model of Data for Large Shared Data Banks".
- Present the data to the user as relations (a presentation in tabular form, i.e. as a collection of tables with each table consisting of a set of rows and columns)
- Provide relational operators to manipulate the data in tabular form.
- As of 2009, most commercial relational DBMSs employ SQL as their query language.

```
dvdrental=# select title, release_year, length, replacement_cost from film
dvdrental-#   where length > 120 and replacement_cost > 29.50
dvdrental-#   order by title desc;
          title           | release_year | length | replacement_cost
--------------------------+--------------+--------+------------------
 West Lion                |         2006 |    159 |            29.99
 Virgin Daisy             |         2006 |    179 |            29.99
 Uncut Suicides           |         2006 |    172 |            29.99
 Tracy Cider              |         2006 |    142 |            29.99
 Song Hedwig              |         2006 |    165 |            29.99
 Slacker Liaisons         |         2006 |    179 |            29.99
 Sassy Packer             |         2006 |    154 |            29.99
 River Outlaw             |         2006 |    149 |            29.99
 Right Cranes             |         2006 |    153 |            29.99
 Quest Mussolini          |         2006 |    177 |            29.99
 Poseidon Forever         |         2006 |    159 |            29.99
 Loathing Legally         |         2006 |    140 |            29.99
 Lawless Vision           |         2006 |    181 |            29.99
 Jingle Sagebrush         |         2006 |    124 |            29.99
 Jericho Mulan            |         2006 |    171 |            29.99
 Japanese Run             |         2006 |    135 |            29.99
 Gilmore Boiled           |         2006 |    163 |            29.99
 Floats Garden            |         2006 |    145 |            29.99
 Fantasia Park            |         2006 |    131 |            29.99
 Extraordinary Conquerer  |         2006 |    122 |            29.99
 Everyone Craft           |         2006 |    163 |            29.99
 Dirty Ace                |         2006 |    147 |            29.99
 Clyde Theory             |         2006 |    139 |            29.99
 Clockwork Paradise       |         2006 |    143 |            29.99
 Ballroom Mockingbird     |         2006 |    173 |            29.99
(25 rows)
```

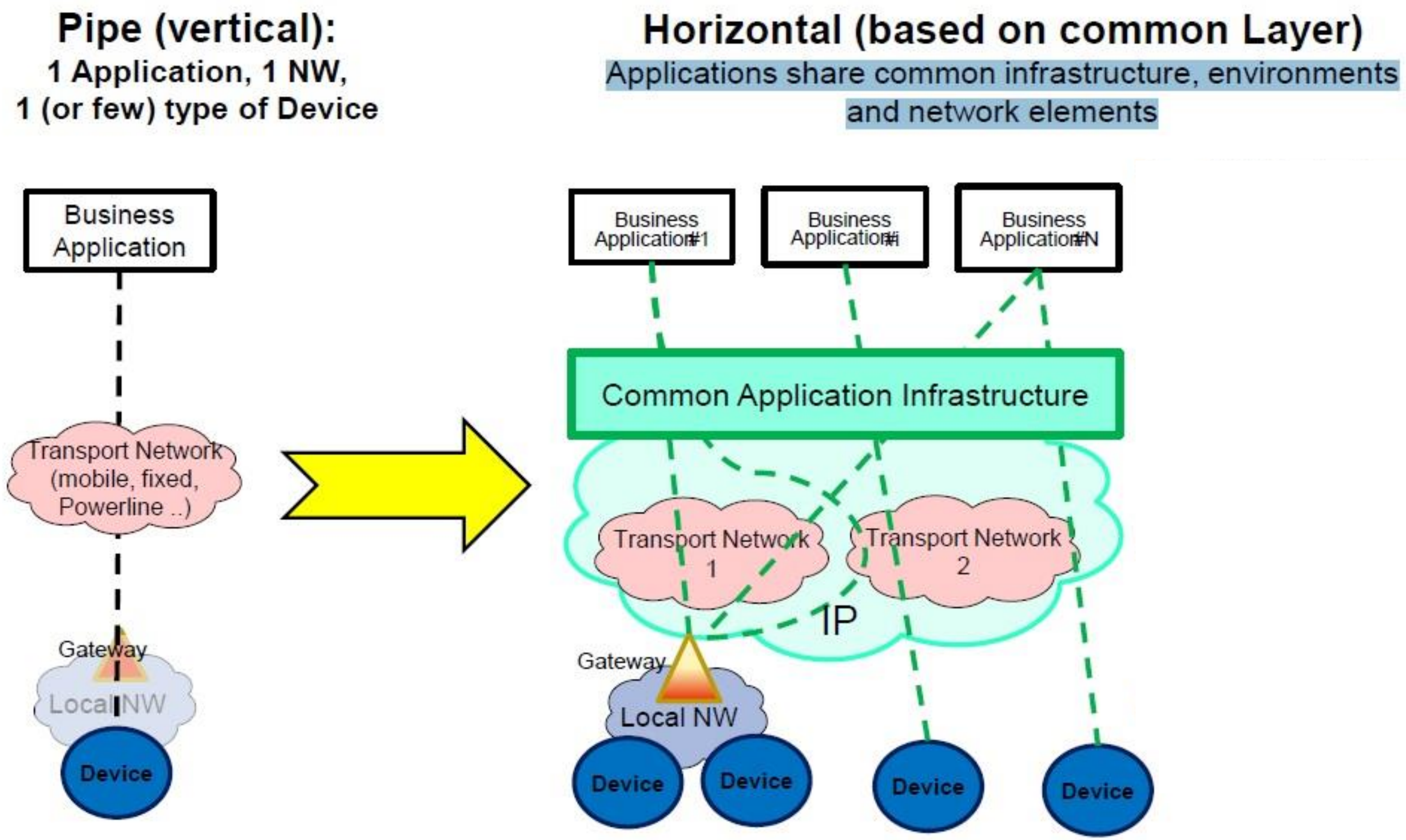
Examples: Oracle, MySQL, Microsoft SQL Server, PostgreSQL, IBM DB2, SQLite

NoSQL and NewSQL Databases

- NoSQL databases – massively distributed, horizontally scalable, fast, do not require fixed table schemas, avoid join operations by storing denormalized data.
- CAP theorem: it is impossible for a distributed system to simultaneously provide consistency, availability, and partition tolerance guarantees –> eventual consistency = high availability and partition tolerance with a reduced level of data consistency.
- NewSQL is a class of modern relational databases that aims to provide the same scalable performance of NoSQL systems for online transaction processing (read-write) workloads while still using SQL and maintaining the ACID guarantees of a traditional database system.

Source: Wikipedia - https://en.wikipedia.org/wiki/Database

Vertical vs. Horizontal Scaling



http://www.iot-week.eu/overview_2013/iot-week-2012/programme-1/tuesday-1/presentations/semantic-interoperability/K1_ETSI-M2M-oneM2M-and-the-need-for-semantics-IoTWeek2012.pdf, By Joerg Swetina (NEC)- ETSI M2M / oneM2M and the need for semantics

NoSQL and NewSQL Database Examples

Type	Notable examples of this type
Wide column	Accumulo, Cassandra, Scylla, HBase
Document:	Apache CouchDB, ArangoDB, BaseX, Clusterpoint, Couchbase, Cosmos DB, eXist-db, IBM Domino, MarkLogic, MongoDB, OrientDB, Qizx, RethinkDB
Key–value:	Aerospike, Apache Ignite, ArangoDB, Berkeley DB, Couchbase, Dynamo, FoundationDB, InfinityDB, MemcacheDB, MUMPS, Oracle NoSQL Database, OrientDB, Redis, Riak, SciDB, SDBM/Flat File dbm, ZooKeeper
Graph:	AllegroGraph, ArangoDB, InfiniteGraph, Apache Giraph, MarkLogic, Neo4J, OrientDB, Virtuoso
New SQL	CockroachDB, Citus, Vitess

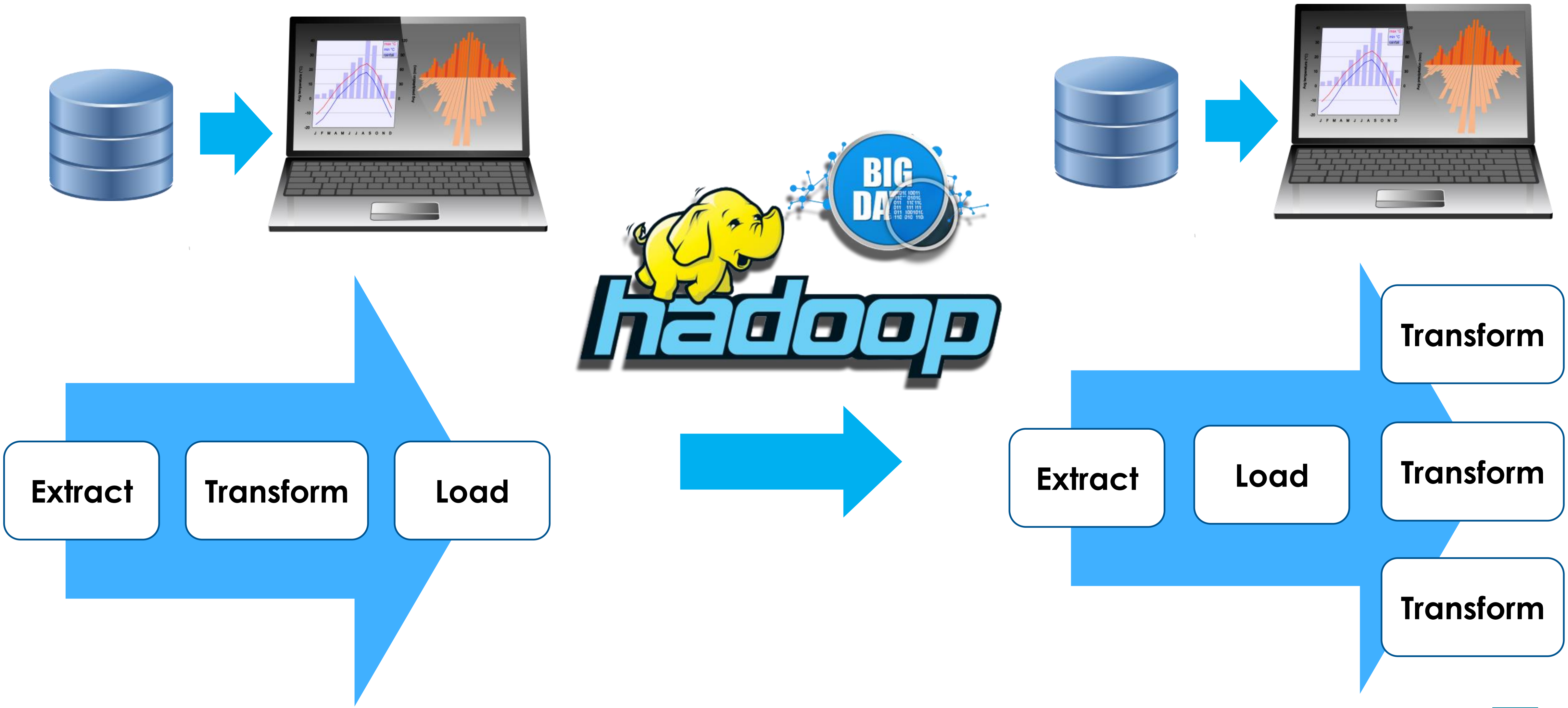
Source: Wikipedia - https://en.wikipedia.org/wiki/NoSQL

SQL and NoSQL Databases Comparison

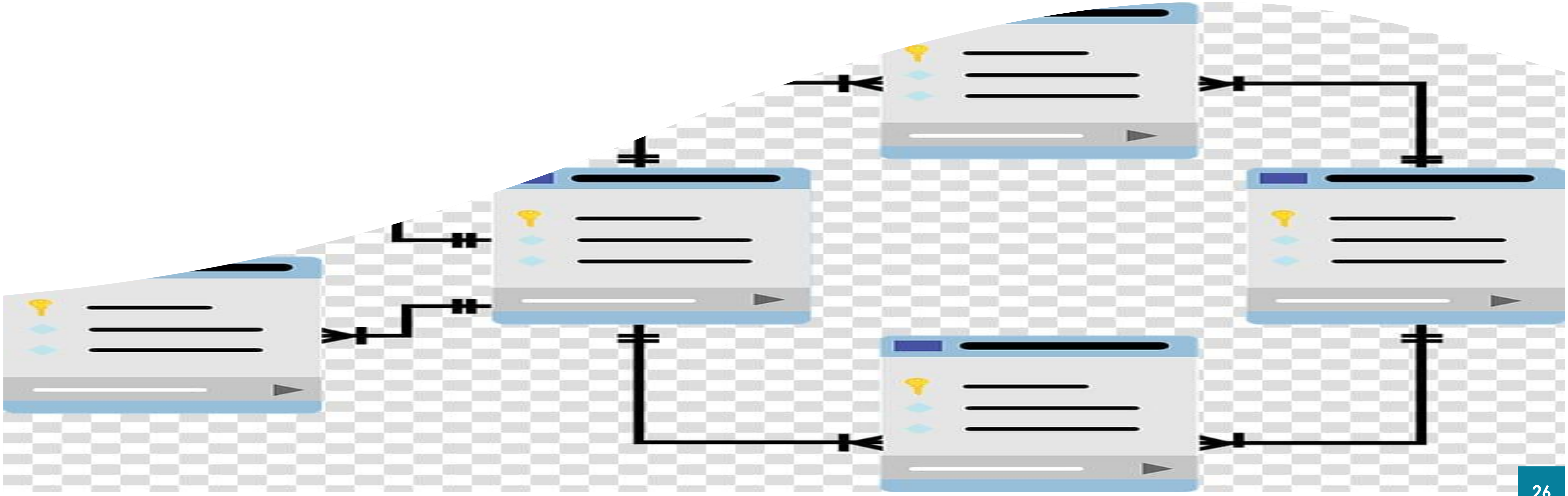
Data model	Performance	Scalability	Flexibility	Complexity	Functionality
Key–value store	high	high	high	none	variable (none)
Column-oriented store	high	high	moderate	low	minimal
Document-oriented store	high	variable (high)	high	low	variable (low)
Graph database	variable	variable	high	high	graph theory
Relational database	variable	variable	low	moderate	relational algebra

Source: Wikipedia - https://en.wikipedia.org/wiki/NoSQL

Batch Processing

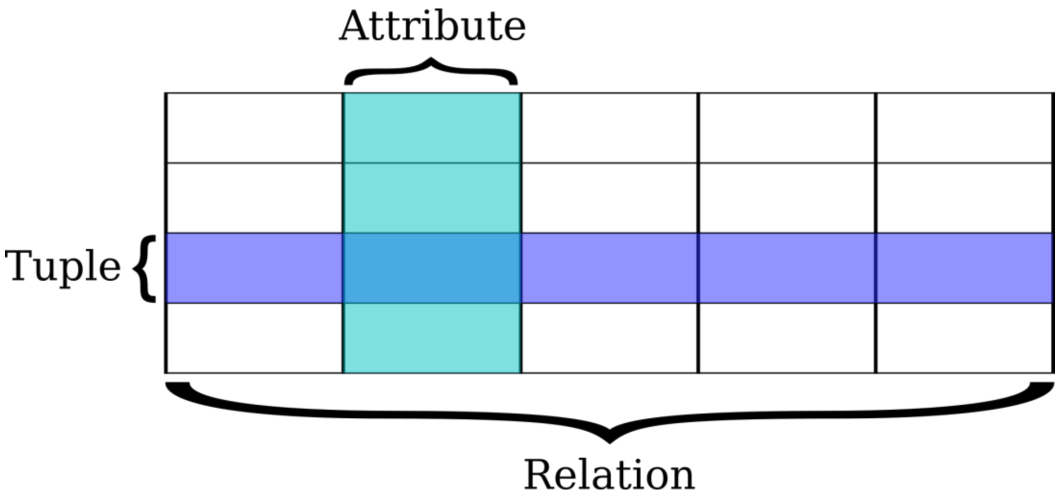


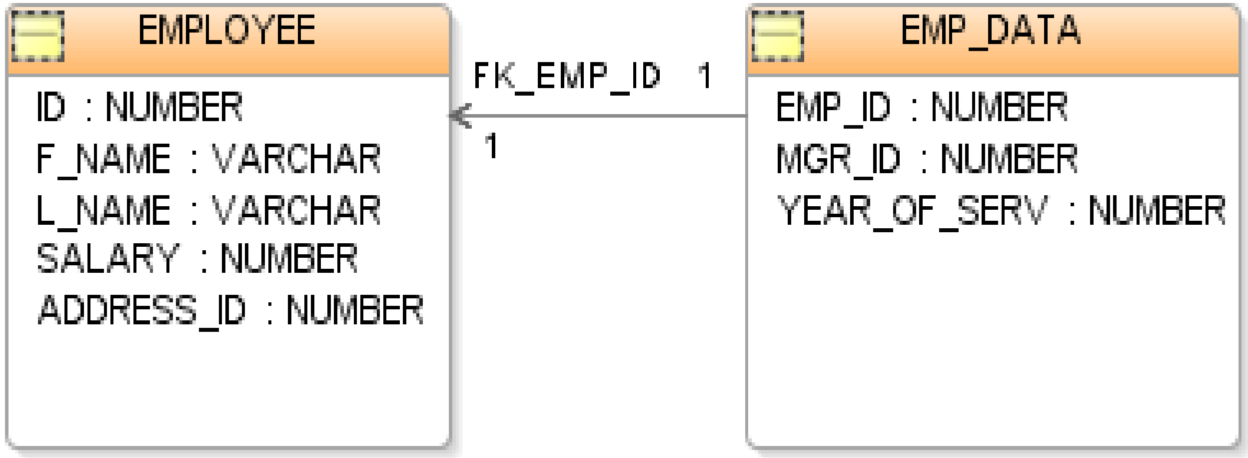
Relational Databases



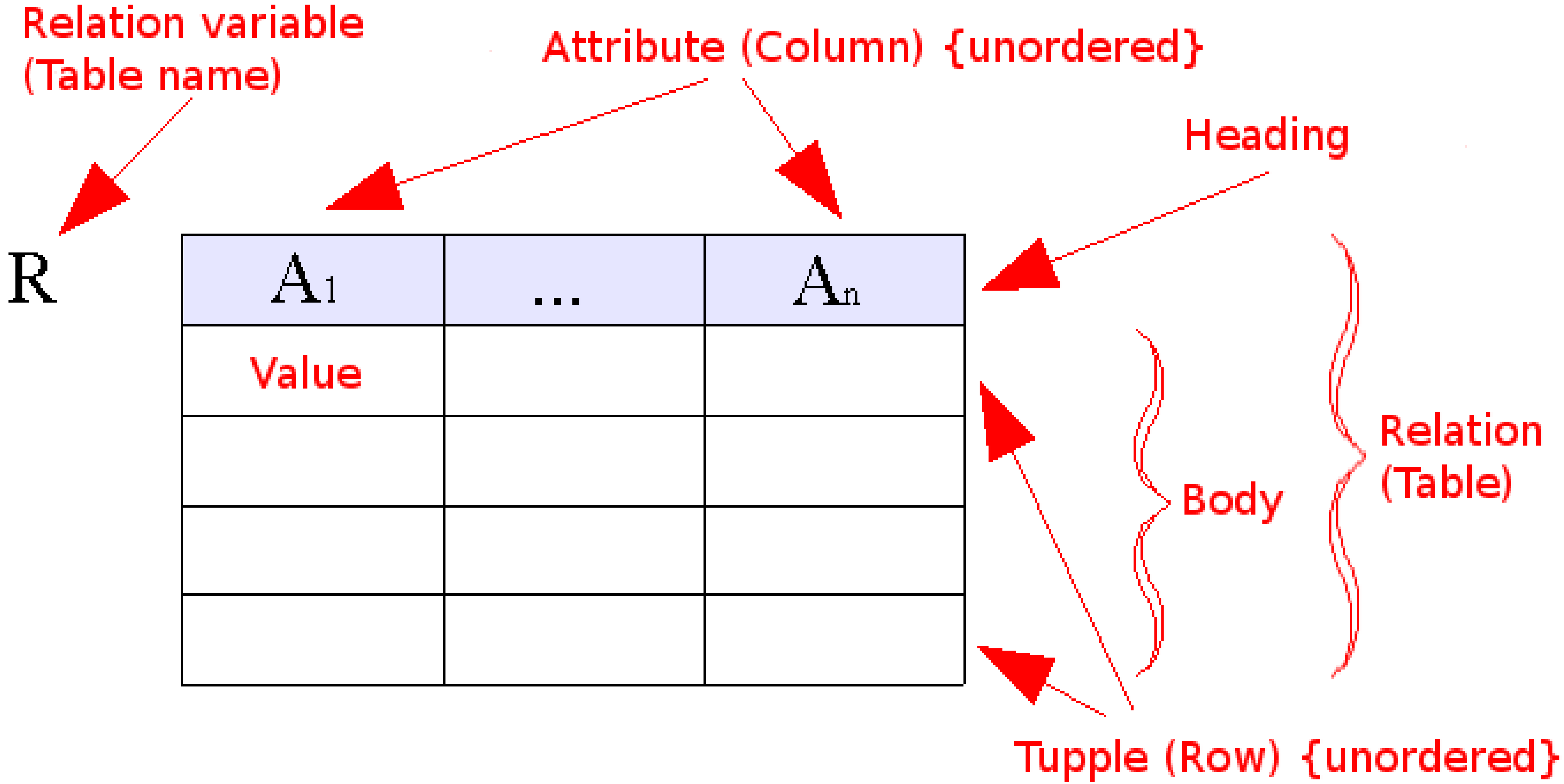
Relational Model

- relation ↔ table
- record, tuple ↔ row
- attribute ↔ column





Relational Model



Views. Domains. Constraints

- Def: Relations which store primary data are called **base relations** or **tables**. Other relations, which are derived from primary relations are **queries** and **views**.

- Def: **Domain** in database is a set of allowed values for a given attribute in a relation – an existing constraint about valid the type of values for given attribute.

- Def: **Constraints** allow more flexible specification of values that are valid for given attribute – e.g. from 1 to 10.

Keys

- **Key** consists of one or more attributes, such that:
  - 1) relation has no two records with the same values for these attributes
  - 2) there is no proper subset of these attributes with the same property
- **Primary Key** is an attribute (less frequently a group of attributes), which uniquely identifies each record (tupple) in the relation
- **Foreign key** is necessary when there exists a relation between two tables – usually it is an attribute in second table referring to primary key of the first table

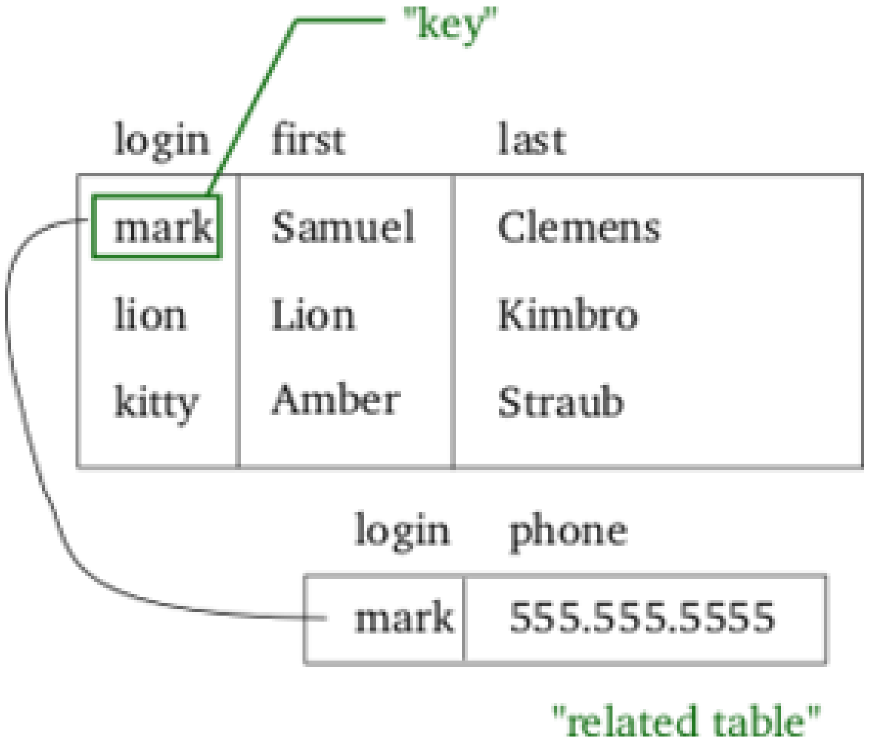
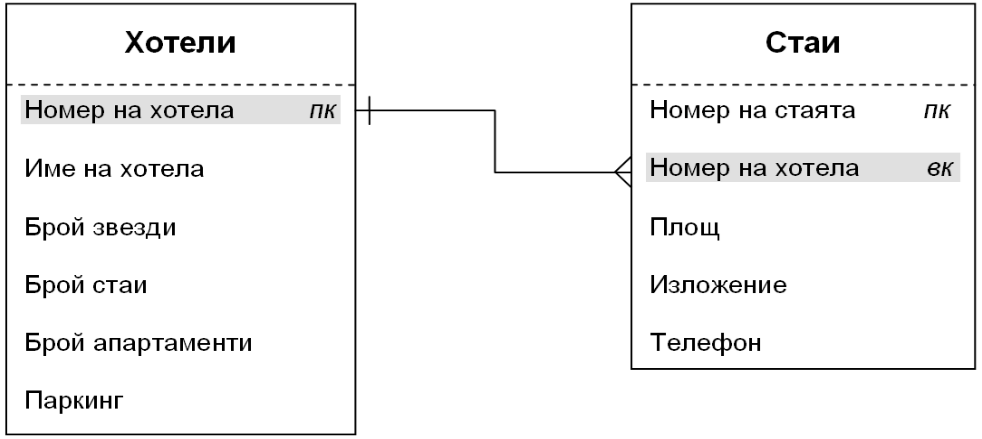
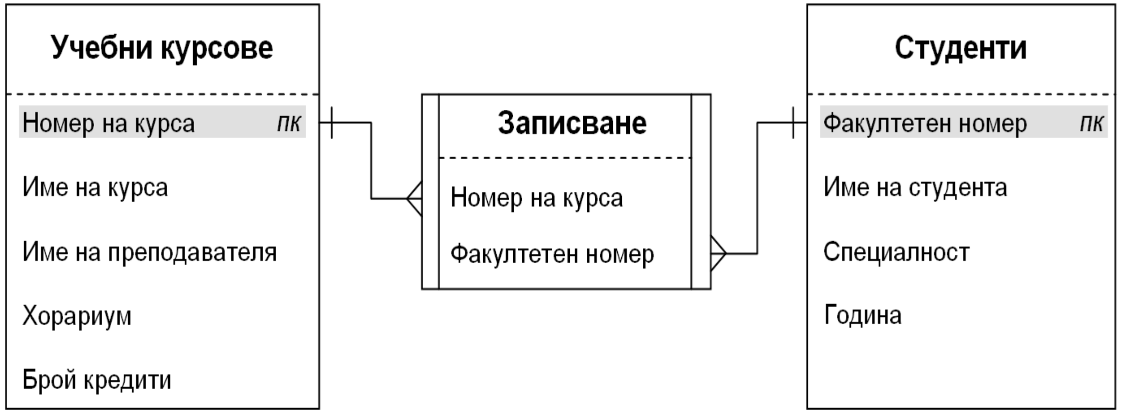


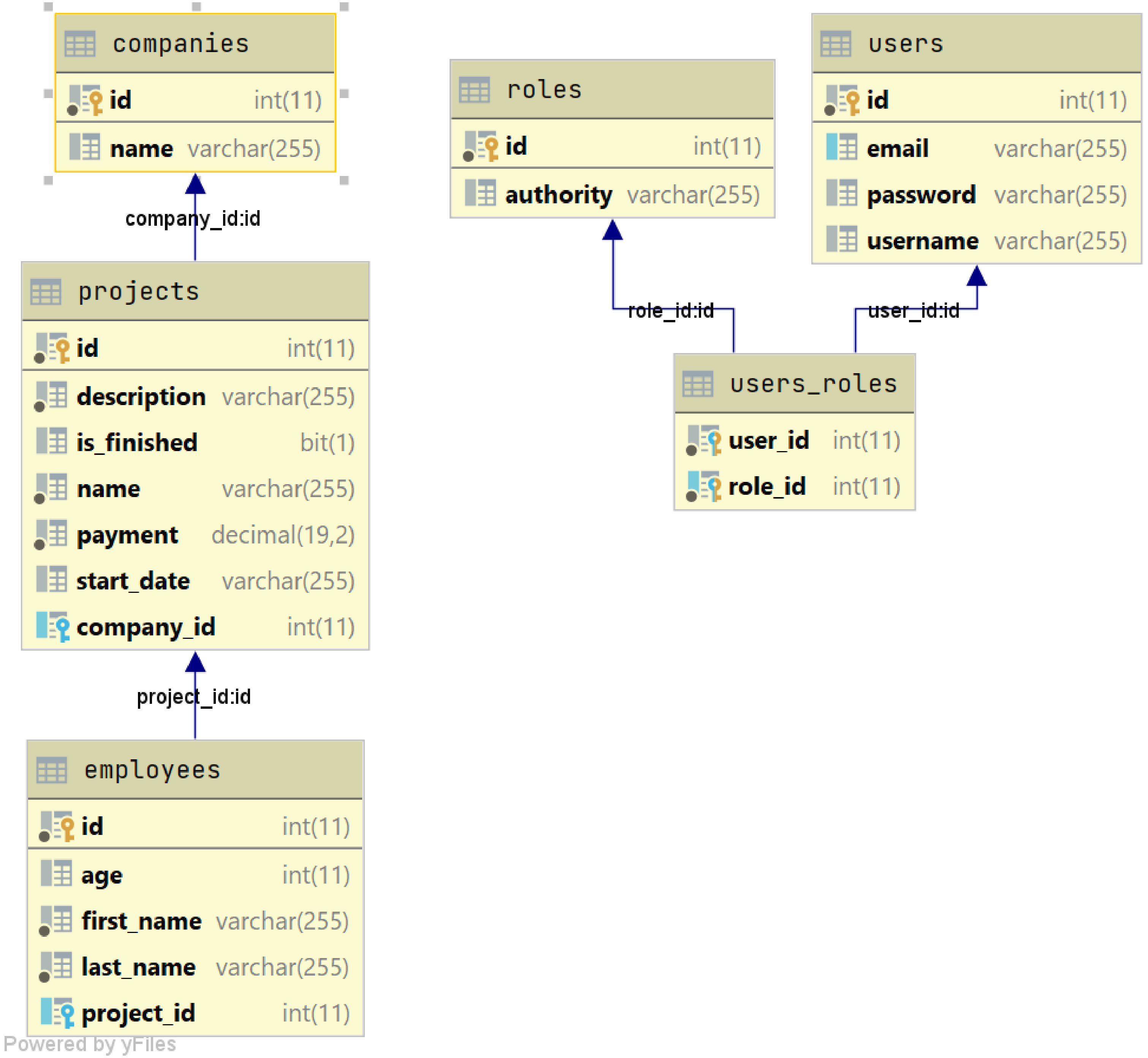
Table Relations. Cardinality

- Relationship is a dependency existing between two tables, when the records from first table can be connected somehow with records from second one.
- Cardinality:
  - One to one (1:1),
  - One to many (1:N),
  - Many to one (N:1)
  - Many to many (M:N)

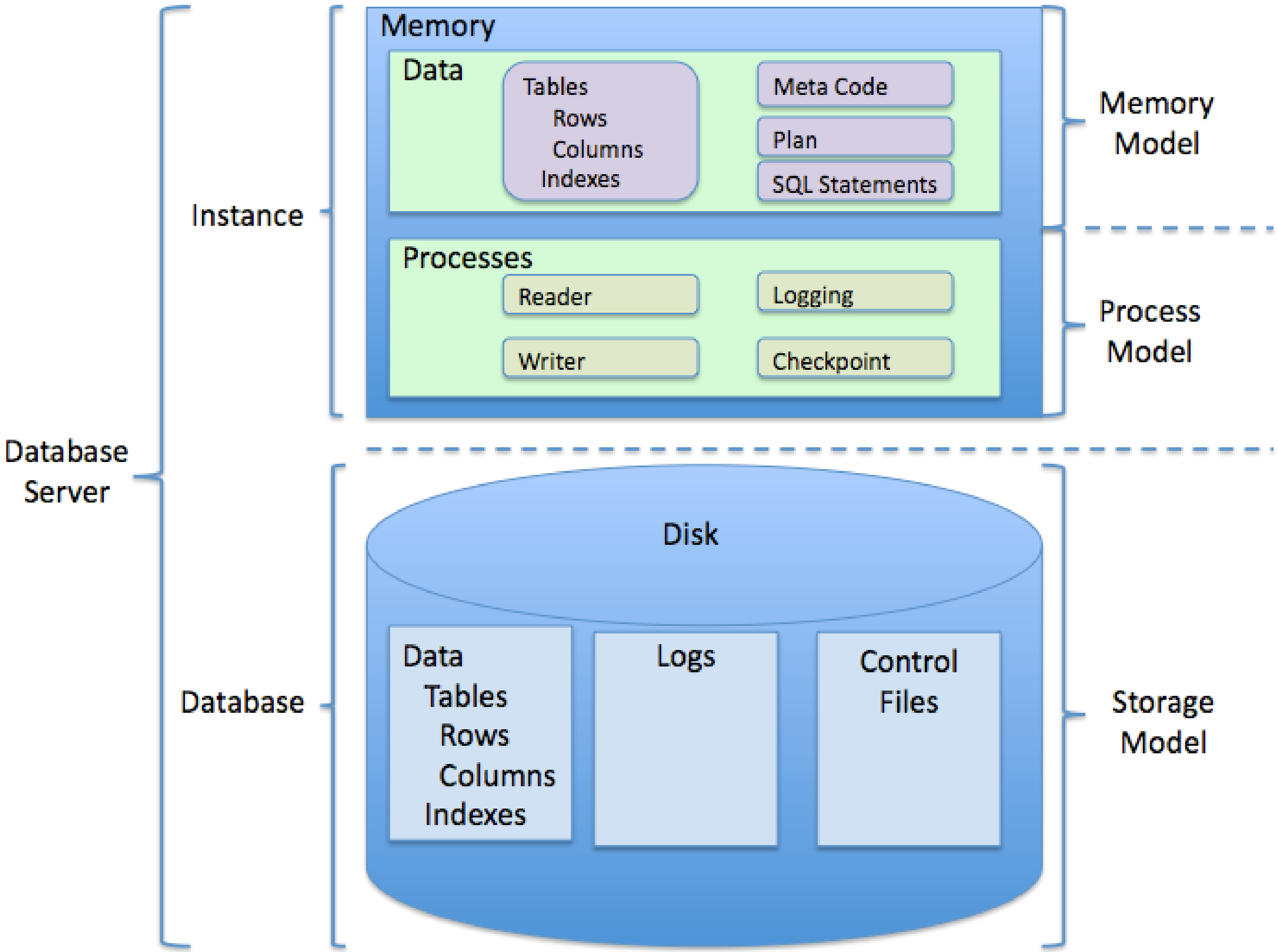




Relational Schema Example ER Model



Relational Database Management System (RDBMS)

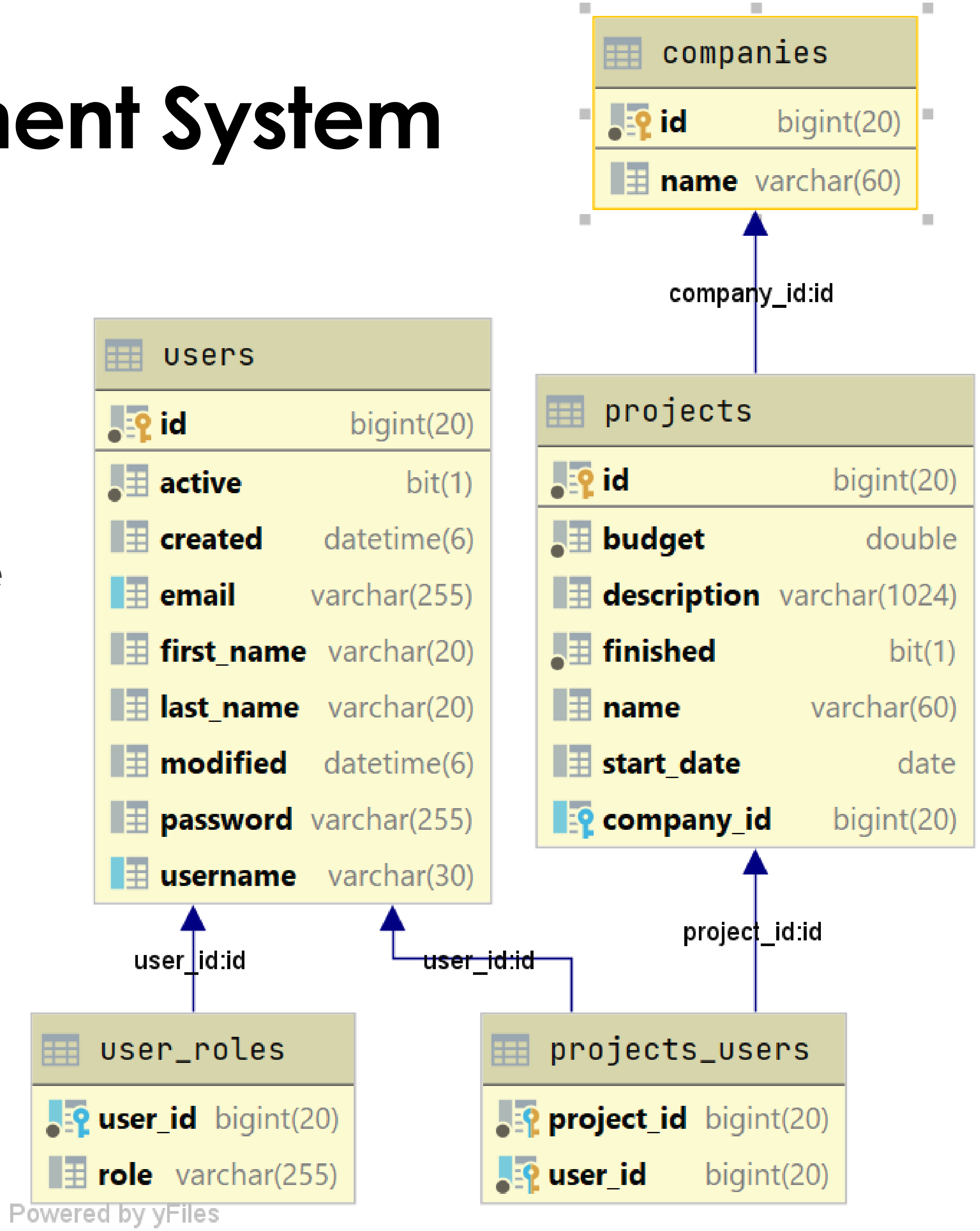


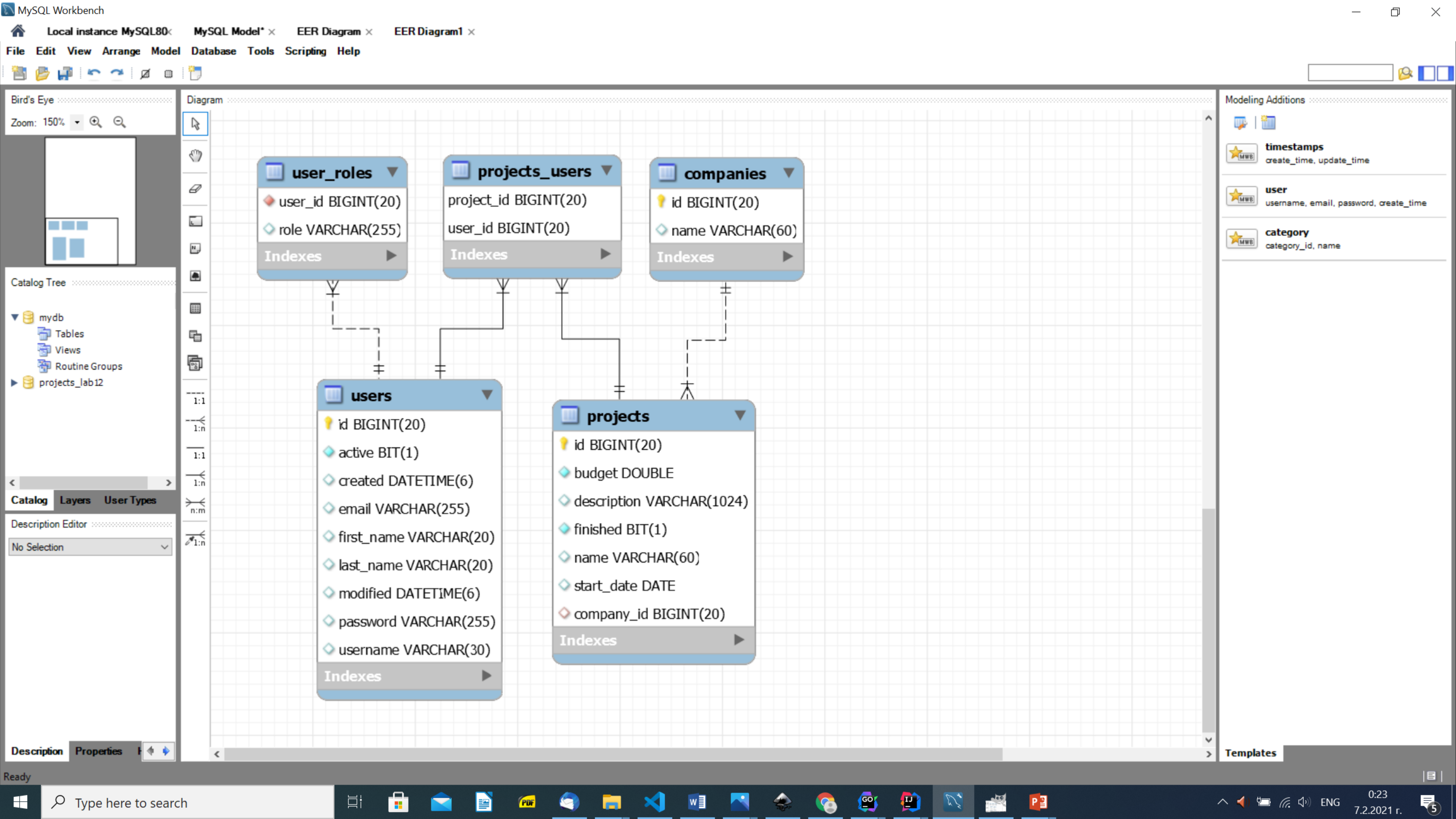
By Scifipete - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=11506013

Accessing Relational Databases with Go – database/sql

Simple Project Management System

- Companies can develop multiple projects
- Each project can involve multiple users (employees)
- Users can have multiple roles in the project management system and can work on multiple projects
- Users should have unique username used for logging in the system together with a password




MySQL Workbench
Local instance MySQL80
MySQL Model*
EER Diagram
EER Diagram1
File Edit View Arrange Model Database Tools Scripting Help
Bird's Eye
Zoom: 150%
Catalog Tree
mydb
Tables
Views
Routine Groups
projects_lab12
Catalog Layers User Types
Description Editor
No Selection
Description Properties
Diagram
user_roles
user_id BIGINT(20)
role VARCHAR(255)
Indexes
projects_users
project_id BIGINT(20)
user_id BIGINT(20)
Indexes
companies
id BIGINT(20)
name VARCHAR(60)
Indexes
users
id BIGINT(20)
active BIT(1)
created DATETIME(6)
email VARCHAR(255)
first_name VARCHAR(20)
last_name VARCHAR(20)
modified DATETIME(6)
password VARCHAR(255)
username VARCHAR(30)
Indexes
projects
id BIGINT(20)
budget DOUBLE
description VARCHAR(1024)
finished BIT(1)
name VARCHAR(60)
start_date DATE
company_id BIGINT(20)
Indexes
1:1
1:n
1:1
1:n
n:m
1:n
Modeling Additions
timestamps
create_time, update_time
user
username, email, password, create_time
category
category_id, name
Templates
Ready
Type here to search
ENG
0:23
7.2.2021 г.

SQL Tutorials and Resources

- W3Schools SQL Tutorial – https://www.w3schools.com/sql/sql_select.asp
- MySQL 8.0 reference Manual – https://dev.mysql.com/doc/refman/8.0/en/
- MySQL Tutorial – https://www.mysqltutorial.org/basic-mysql-tutorial.aspx
- W3Resource MySQL Tutorial – https://www.w3resource.com/mysql/mysql-tutorials.php

database/sql: https://golang.org/pkg/database/sql/

- Create a connections pool to MySQL DB:

```
db, err := sql.Open("mysql", "root:root@/golang_projects?parseTime=true")
if err != nil {
		log.Fatal(err)
}
defer db.Close()
```

- Can add more settings to *sql.DB:

```
db.SetConnMaxLifetime(time.Minute * 5) // ensure connections are closed by the //driver safely before MySQL server, OS, or other middlewares, helps load balancing
db.SetMaxOpenConns(10) // maximum size of connection pool
db.SetMaxIdleConns(10) // maximum size of idle connections in the pool
db.SetConnMaxIdleTime(time.Minute * 3) // maximum time connection is kept if idle
```

database/sql: Ping the DB:

```go
ctx, cancel := context.WithTimeout(context.Background(), 1*time.Second)
defer cancel()

status := "up"
if err := db.PingContext(ctx); err != nil {
		status = "down"
}


log.Println(status)
```

database/sql: Simple SELECT Query

```
func FindAllProjects(db *sql.DB) (projects []entities.Project, err error) {
    rows, err := db.Query("SELECT * FROM projects")
    if err != nil {
        return
    }
    defer rows.Close()
    for rows.Next() {
        p := entities.Project{}
        err = rows.Scan(&p.ID, &p.Name, &p.Description, &p.Budget, &p.Finished, &p.StartDate,&p.CompID)
        if err != nil {
            return
        }
        projects = append(projects, p)
    }
    if err = rows.Err(); err != nil {
        return
    }
    return
}
```

database/sql: Better SELECT Query

```
func FindAllProjects(db *sql.DB) (projects []entities.Project, err error) {
    rows, err := db.Query("SELECT * FROM projects")
    if err != nil { return }
    defer rows.Close()
    for rows.Next() {
        p := entities.Project{}
        err = rows.Scan(&p.ID, &p.Name, &p.Description, &p.Budget, &p.Finished, &p.StartDate,&p.CompID)
        if err != nil { return }
        projects = append(projects, p)
    }
    // If the database is being written to ensure to check for Close errors that may be returned from the driver. The
    // query may encounter an auto-commit error and be forced to rollback changes.
    err = rows.Close()
    if err != nil {
        return
    }
    // Rows.Err will report the last error encountered by Rows.Scan.
    if err = rows.Err(); err != nil { return }
    return
}
```

database/sql: Prepared Statement – INSERT

```
stmt, err = db.Prepare(`INSERT INTO projects(name, description , budget, start_date, finished, company_id)
                        VALUES( ?, ?, ?, ?, ?, ? )`)
if err != nil { log.Fatal(err) }
defer stmt.Close() // Prepared statements take up server resources and should be closed after use.

for i, _ := range projects {
    projects[i].Finished = true
    result, err := stmt.Exec(projects[i].Name, projects[i].Description, projects[i].Budget, projects[i].StartDate,
            projects[i].Finished, projects[i].CompanyId);
    if err != nil { log.Fatal(err) }
    numRows, err := result.RowsAffected()
    if err != nil ||  numRows != 1 { log.Fatal("Error creating new Project", err) }
    insId, err := result.LastInsertId()
    if err != nil { log.Fatal(err) }
    projects[i].Id = insId
}
```

Transactions and Concurrency

- **Transaction** = **Business Event**
- **ACID rules:**
- **Atomicity** – the whole transaction is completed (commit) or no part is completed at all (rollback).
- **Consistency** – transaction should presetve existing integrity constraints
- **Isolation** – two uncompleted transactions can not interact
- **Durability** – successfully completed transactions can not be rolled back

Transaction Isolation Levels

- DEFAULT - use the default isolation level of the underlying datastore
- READ_UNCOMMITTED – dirty reads, non-repeatable reads and phantom reads can occur
- READ_COMMITTED – prevents dirty reads; non-repeatable reads and phantom reads can occur
- REPEATABLE_READ – prevents dirty reads and non-repeatable reads; phantom reads can occur
- SERIALIZABLE – prevents dirty reads, non-repeatable reads and phantom reads

Source: https://docs.spring.io/spring-framework/docs/

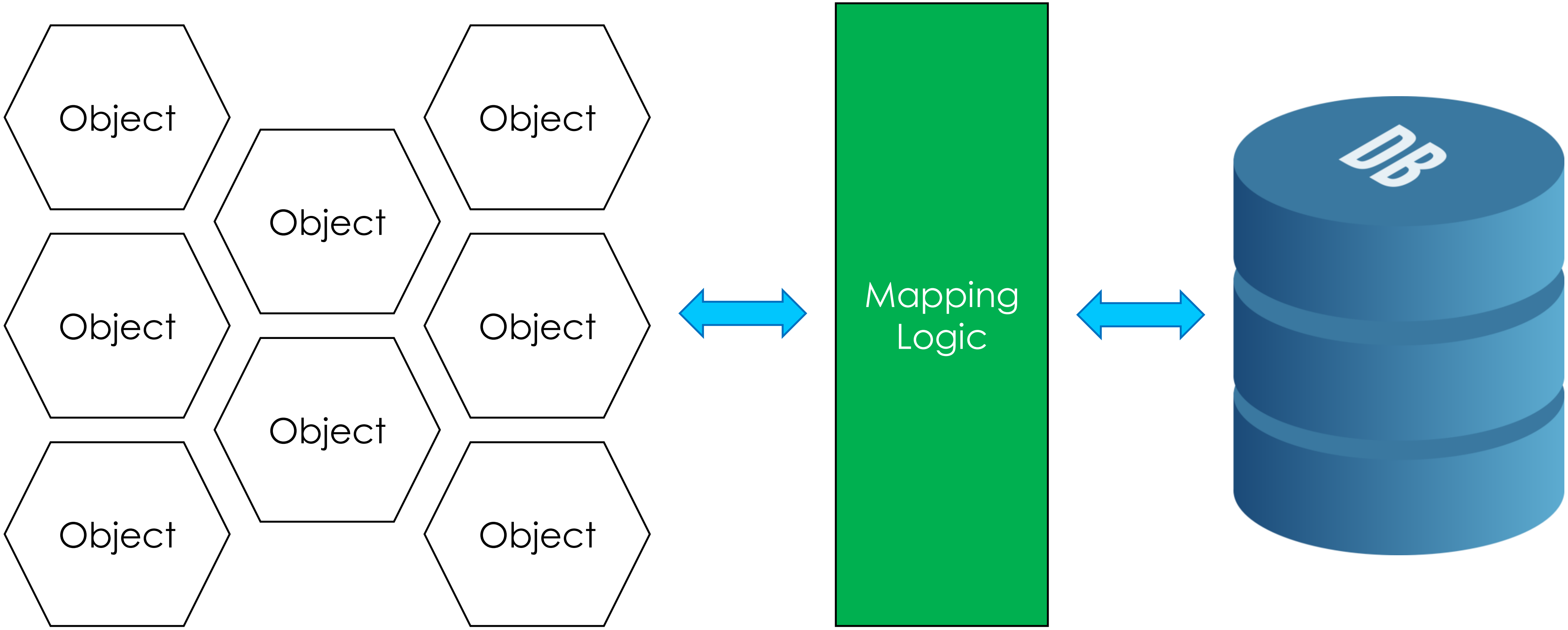
database/sql: Update Project Budgets in Transaction

```go
tx, err := db.BeginTx(ctx, &sql.TxOptions{Isolation: sql.LevelSerializable}) // or db.BeginTx()
if err != nil { log.Fatal(err) }
result, execErr := tx.ExecContext(ctx, `UPDATE projects SET budget = ROUND(budget * 1.2)
                                        WHERE start_date > ?;`, startDate)
if execErr != nil {
        if rollbackErr := tx.Rollback(); rollbackErr != nil {
                log.Fatalf("update failed: %v, unable to rollback: %v\n", execErr, rollbackErr)
        }
        log.Fatalf("update failed: %v", execErr)
}
rows, err := result.RowsAffected()
if err != nil { log.Fatal(err) }
log.Printf("Total budgets updated: %d\n", rows)

if err := tx.Commit(); err != nil {
        log.Fatal(err)
}
```

Go Object to Relation Mapping with GORM

Object To Relational Mapping (ORM)



gorm.io/gorm: https://gorm.io/

```
dsn := "root:root@tcp(127.0.0.1:3306)/gorm_projects?charset=utf8mb4&parseTime=True&loc=Local“
db, err := gorm.Open(mysql.Open(dsn), &gorm.Config{})
if err != nil { log.Fatal(err) }
user := entities.User{FirstName: "Rob", LastName: "Pike2", Email: "pike2@golang.com", Username: "rob2",   Password: "rob", Active: true, Model: gorm.Model{CreatedAt: time.Now(), UpdatedAt: time.Now()}}

result := db.Create(&user) // pass pointer of data to Create

if result.Error != nil {
		log.Fatal(result.Error) // returns error
}
fmt.Printf("New user created with ID: %d -> %+v\nRows afffected: %d\n",
		user.ID, // returns inserted data's primary key
		user,
		result.RowsAffected, // returns inserted records count
)
```

gorm.io/gorm: Detiled Configuration

```
db, err := gorm.Open(mysql.New(mysql.Config{
        DSN: "root:root@tcp(127.0.0.1:3306)/golang_projects?charset=utf8&parseTime=True&loc=Local",
        DefaultStringSize: 256, // default size for string fields
        DisableDatetimePrecision: true, // disable datetime precision, which not supported before MySQL 5.6
        DontSupportRenameIndex: true, // drop & create when rename index (not supported before MySQL 5.7)
        DontSupportRenameColumn: true, // `change` when rename column (not supported before MySQL 8)
        SkipInitializeWithVersion: false, // auto configure based on currently MySQL version
}), &gorm.Config{})
```

gorm.io/gorm: Batch User Creation

```
db.AutoMigrate(&entities.User{})        // Automatically create database schema – all the tables
db.AutoMigrate(&entities.Company{})
db.AutoMigrate(&entities.Project{})
users := []entities.User{
    {FirstName: "Linus", LastName: "Torvalds", Email: "linus@linux.com", Username: "linus", Password: "linus",
                    Active: true, Model: gorm.Model{CreatedAt: time.Now(), UpdatedAt: time.Now()}},
    {FirstName: "Rob", LastName: "Pike", Email: "pike@golang.com", Username: "rob", Password: "rob",
                    Active: true, Model: gorm.Model{CreatedAt: time.Now(), UpdatedAt: time.Now()}},
}
result := db.Create(&users) // pass pointer of data to Create
//db.CreateInBatches(users, 100) // batch size 100
if result.Error != nil { log.Fatal(result.Error) } // returns error
fmt.Printf("New users created with IDs: ")
for _, user := range users {    fmt.Printf("%d, ", user.ID) }
```

gorm.io/gorm: … and Query

```
result = db.Find(&users)          // Get all users - SELECT * FROM users;

if result.Error != nil {          // if returns error

        log.Fatal(result.Error)
}

fmt.Printf("Number of users: %d\n", result.RowsAffected) // returns found records count, equals `len(users)`

utils.PrintUsers(users)
```

gorm.io/gorm: Preloading (Prefetching) Associations

```
result = db.Preload(clause.Associations).Find(&companies) // SELECT * FROM companies fetching projects
if result.Error != nil {
        log.Fatal(result.Error) // returns error
}
fmt.Printf("Number of companies: %d\n", result.RowsAffected)// returns found records count, equals `len(users)`
utils.PrintCompanies(companies)
```

```
result = db.Preload(clause.Associations).Find(&projects)    // SELECT * FROM users with associations
if result.Error != nil { log.Fatal(result.Error) } // returns error
err = db.Model(&(projects[0])).Association("Users").Find(&users) // Association mode
if err != nil { log.Fatal(result.Error) } // returns error
fmt.Printf("Users in Project '%s': %v\n", projects[0].Name, users)
```

```
db.Session(&gorm.Session{FullSaveAssociations: true}).Updates(&user) // Saving all associations
```

Common Pitfalls when Using RDBs with Go - I

- Deferring rows.Close() inside a loop → memory and connections
- Opening many dbobjects (sql.Db) → many TCP connections in TIME_WAIT
- Not doing rows.Close()when done → Run rows.Close() as soon as possible, you can run it later again (no problem). Chain db.QueryRow() & .Scan()
- Unnecessaey use of prepared statements → if concurrency is high, consider whether prepared statements are necessary → re-prepared on busy connections → should be used only if executed many times
- Too much strconv or casts → let conversions to .Scan()
- Custom error-handling and retry → database/sql should handle connection pooling, reconnecting, and retrys

Source: Common Pitfalls When Using database/sql in Go: [*https://orangematter.solarwinds.com/2017/03/23/common-pitfalls-when-using-database-sql-in-go/*](https://orangematter.solarwinds.com/2017/03/23/common-pitfalls-when-using-database-sql-in-go/)

Common Pitfalls when Using RDBs with Go - II

- Don’t forgetting to check errors after **rows.Next()** → rows.Next() can exit with error
- Using **db.Query()** for **non-SELECT** queries → iterating over a result set when there is no one, leaking connections.
- Don’t assuming subsequent statements are executed on same connection → Two statements can run on different connections → to solve the problem execute all statements on a single transaction (**sql.Tx**).
- Don’t mix **db** access while using a **tx** → **sql.Tx** is bound to transaction, **db** not
- Unexpected **NULL** → to scan for NULL use one of the **NullXXX** types provided by the database/sql package – e.g. NullString

Source: *Common Pitfalls When Using database/sql in Go: https://orangematter.solarwinds.com/2017/03/23/common-pitfalls-when-using-database-sql-in-go/*

Recommended Literature

- The Go Documentation - https://golang.org/doc/
- The Go Bible: Effective Go - https://golang.org/doc/effective_go.html
- David Chisnall, *The Go Programming Language Phrasebook*, Addison Wesley, 2012
- Alan A. A. Donovan, Brian W. Kernighan, *The Go Programming Language*, Addison Wesley, 2016
- Nathan Youngman, Roger Peppé, *Get Programming with Go*, Manning, 2018
- Naren Yellavula, *Building RESTful Web Services with Go*, Packt, 2017

Thank's for Your Attention!

Trayan Iliev

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