Lecture 6. Database Application programing with SQL, Python

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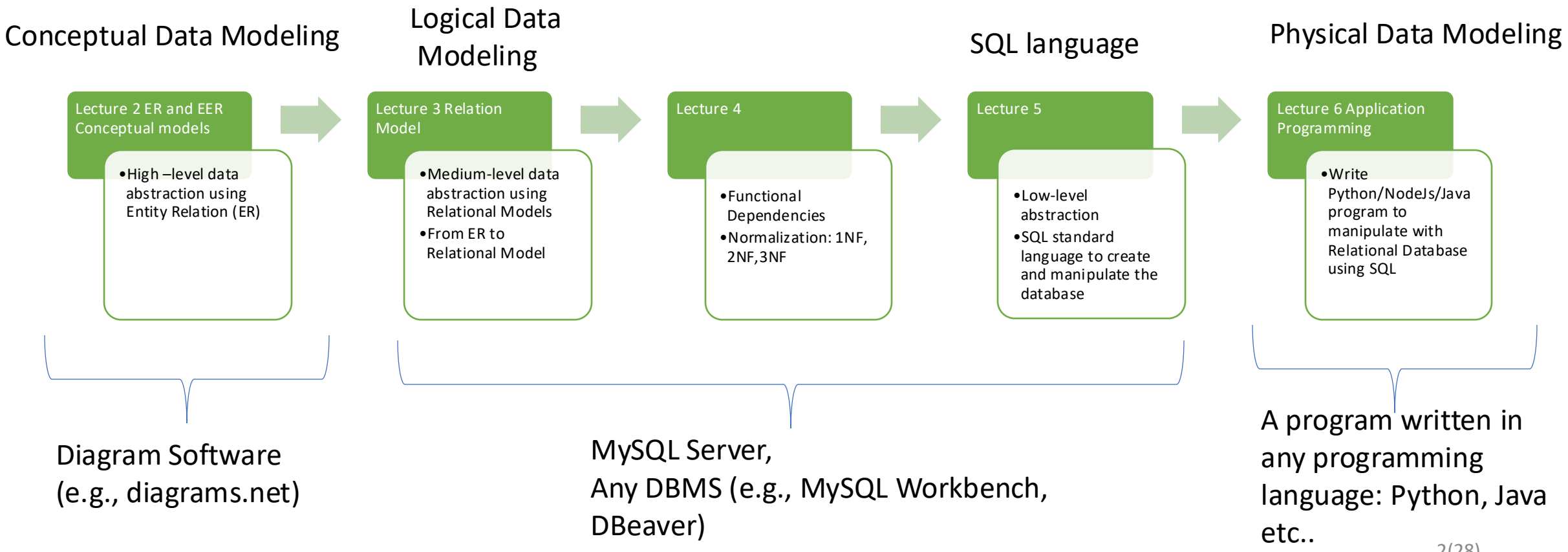
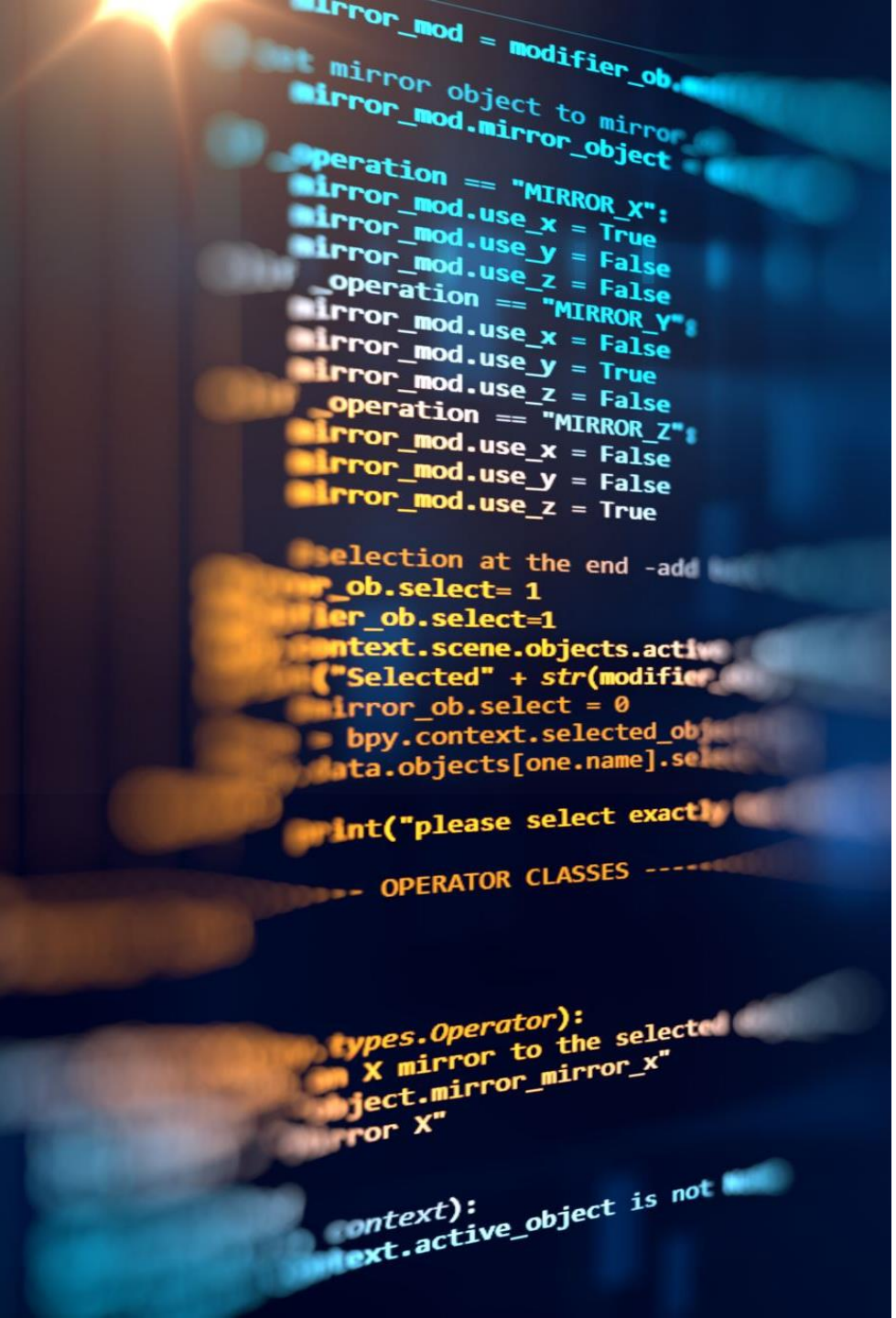
Connection to previous lectures





Outline

- Database Programming Techniques and Issues (Chapter 10)
- Python Database Application Programming (see References)

Introduction to SQL Programming Techniques

- Most database access is accomplished through software programs that implement database applications.
- This programs usually developed in different programming languages: Java, C#, Python, C/C++, JavaScript, PHP
- There are whole books devoted to each database programming technique. New techniques are developed all the time, and updates for existing techniques are also evolving.
- Although there are SQL standards exists which are continually evolving and each DMBS may have some variations from the standard.

Overview of main approaches for accessing a database from programs

- **Approach 1. Embedding database commands in a programming language.** The database statements are marked with special syntax which is recognized by the precompiler or preprocessor.
- **Approach 2. Using a library of database functions.** This is the most common approach to access the database though library written for specific programming language (Python, Java, PhP, etc.). It provides ready functions to connect to a database, prepare and execute queries. Nowadays this approach is known as ***application programming interface (API)***.
- **Approach 3. Designing a new database programming language**.

Approach 2 Issues

- **Data type mismatch**: *data types* of the programming language (e.g., Python, Java, etc.) differ from the *attribute types* available in SQL DBMS.
  - *Consequences*: program crashed, or SQL transaction (query) is failed.
  - *Solution*: a *binding* between attribute types (SQL) and compatible data type of *programming language* have to be performed. The values sets should be also check in the program side before performing the parsing data or data convertation, especially for dates data type.
- **Data structure:** the data structure which comes from SQL is set of tuples, like this [('att1', 'att2', 'att3',..),(),(),()…]. In order to access the individual tuple's elements, you need a binding to map query result data structure to an appropriate data structure in the programming language.
  - *Solution*: A general function is needed to loop over the tuples in a query result and re-structure the data in more convenient data structure (e.g., dictionaries in Python). Also, you need to have another function which maps the programming language structure to set of tuples (SQL) for updating/inserting operations to database.

Why Database Return Tuples?

- Tuples:
  - Tuples are ordered collections of elements.
  - They are immutable, meaning once created, the elements within a tuple cannot be changed.
  - Tuples are created using parentheses ( ) or the tuple() constructor.
  - Elements in a tuple are accessed by their index.
  - Tuples are often used to store heterogeneous data (data of different types) and are ideal for situations where the order of elements matters.
  - Example: ('Oskar Andersson', 2003, 'M')
- Dictionaries:
  - Dictionaries are unordered collections of key-value pairs.
  - They are mutable, meaning you can add, remove, or modify key-value pairs after creating the dictionary.
  - Dictionaries are created using curly braces { } or the dict() constructor.
  - Elements in a dictionary are accessed by their keys rather than by their index.
  - Dictionaries are often used to store mappings between unique keys and their associated values.
  - Example: {'name': 'Oskar Andersson', 'byear':2003, 'gender' : 'M'}

General Programming Workflow

Setting up database:

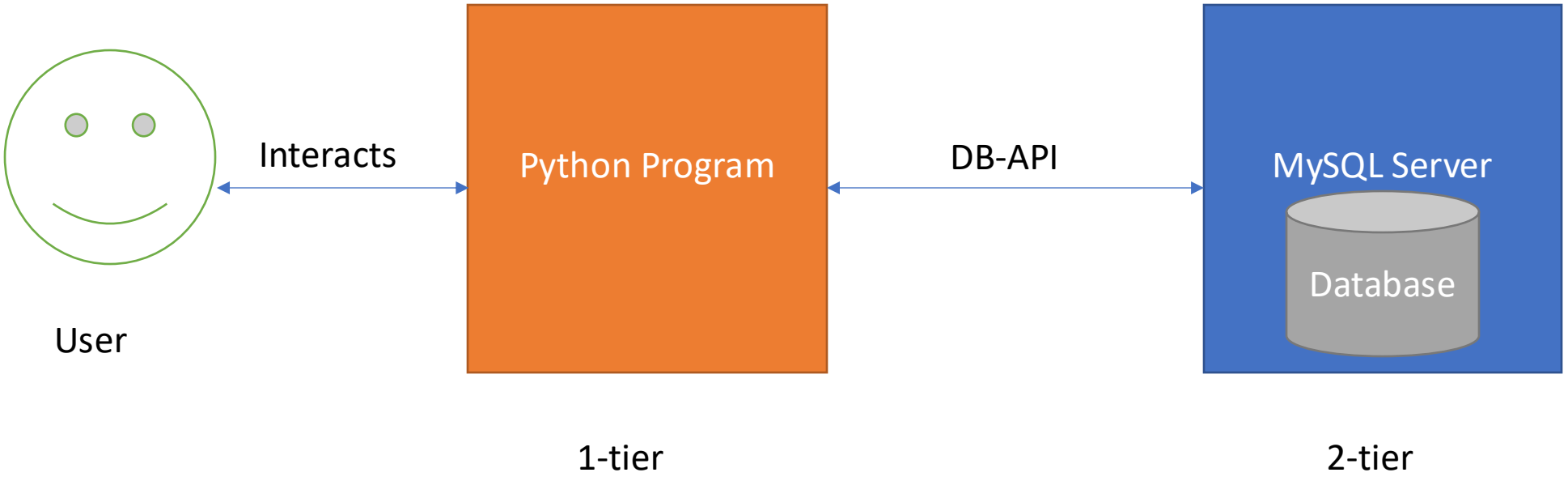
- Run MySQL Server
- Use any DBMS to connect to MySQL server
- Create a database using DBMS interactive interface
- Define database schema using DBMS interactive interface

Writing Database Application/Program:

- Establish the connection to MySQL Server and database. In this step, we specify the URL address (e.g., localhost) of the machine where the database server is located, and providing a login account name and password for database access. Note! In real life application we do not use an admin (root) user to access the database. The database admin have to create a new user with read and write access for each database application/program. This user must not have access to modify the database schemes (such as delete tables, adding new tables)
- Once the database connection is established, the program can interact with the database by submitting queries commands.
- When the program no need anymore access to the database, it should *terminate* or *close* the connection to the database.

Overview of Python Database Programming

Python Database 2-tier Architecture



DB-API for Python

- The Python DB API is a widely used module that provides a database application programming interface
- Python DB-API is independent of any database engine, which enables you to write Python scripts to access any database engine
- The Python DB API implementation for MySQL is MySQLdb
- MySQLdb version 1 is not supported anymore
- MySQLdb version 2 is outdated and migrated to so called mysqlclient library
- There are other DB-API exists: Benchmarking MySQL drivers (Python 3.4) among them is MySQL Connector API which we are going to use in this course

MySQL Connector API

- MySQL provides MySQL adapter called MySQL connector API (written in Python and does not require any third-party libary) which enables Python programs to access MySQL databases.
- This adapter allows the conversion between Python and MySQL data types
- It includes:
  - Connection
  - Cursor for querying the data (API documentation)
  - Handling exceptions (API documentation)

MySQL Connection Class

- Connection class is used to open and manage a connection to a MySQL server. It also used to send commands and SQL statements and read the results.
- Most common methods used are:
  - connect()
  - cursor()
  - commit()
  - is_connected()
  - close()
  - And many more….
- Read more about this class in:
  - API documentation

MySQL Cursor Class

- The MySQLCursor class instantiates objects that can execute operations such as SQL statements. Cursor objects interact with the MySQL server using a MySQLConnection object.
- Most common methods used are:
  - *execute()* – to run one SQL statement
  - *executemany()* – to run execute the same SQL statement many times (e.g., when we want to insert several records).
  - *fetchall()* – to retrieve all the rows from the result set at once and process them as a whole
  - *fetchmany()* – to fetch rows in batches rather than all at once, which can be more memory-efficient, especially for large result sets. The *size* parameter specifies the number of rows to fetch. If not provided, it defaults to the cursor's arraysize attribute, which you can set using cursor.arraysize.
  - *fetchone()* – to fetch the result set one row at a time and want to process each row individually

Read more: API Documentation

Example

```python
import mysql.connector

# Establish connection
conn = mysql.connector.connect(user='username', password='password',

# Create cursor
cursor = conn.cursor()

# Execute query
cursor.execute('SELECT * FROM my_table')

# Fetch all rows
all_rows = cursor.fetchall()
print("All rows:", all_rows)

# Fetch three rows
three_rows = cursor.fetchmany(3)
print("Three rows:", three_rows)

# Fetch one row at a time using explicit fetchone()
row = cursor.fetchone()
while row:
    print("One row:", row)
    row = cursor.fetchone()

#Fetch row one by one using implicit fetchone()
for row in cursor:
    print(row)

# Close cursor and connection
cursor.close()
conn.close()
```

Using *fetchone*() and *fetchmany*()

- Exception: mysql.connector.errors.InternalError: Unread result found
- Solutions:
  - Use LIMIT on your query
  - use fetchall() instead fetchone()
  - Use fetchall() after fetchone() with try and except statement
  - Use cursor.reset()

Example:

```
cursor.execute("SELECT fname FROM employee") #execute query
fname = cursor.fetchone()[0] # fetch first result
print(fname) #print into console
cursor.execute("SELECT lname FROM employee")  # Exception: Unread result found.
```

Solution 1: Use LIMIT

```
cursor.execute("SELECT fname FROM employee LIMIT 0,1") #execute query
fname = cursor.fetchone()[0] # fetch first result
print(fname) #print into console
cursor.execute("SELECT lname FROM employee")  # OK.
```

Solution 2: Use fetchall() after fetchone():

```
cursor.execute("SELECT fname FROM employee") #execute query
fname = cursor.fetchone()[0] # fetch first result
print(fname) #print into console
try:
    cursor.fetchall()  # fetch (and discard) remaining rows
except mysql.connector.errors.InterfaceError as ie:
    if ie.msg == 'No result set to fetch from.':
        # we are at the end of the result set
        pass
    else:
        raise
cursor.execute("SELECT lname FROM employee")  # OK.
```

Cursor-based Approach

- Create a cursor:
  - cursor = connection.cursor()
  - Cursor allows you to navigate through the rows and fetch them one by one or in batches.
- Execute a query or a SQL statement:
  - cursor.execute('SELECT * FROM employees')
  - this query returns a list of tuples stored in the cursor object.
- Fetch Rows:
  - cursor.fetchone()
  - cursor.fetchmany(size)
  - cursor.fetchall()
  - for row in cursor:
    print(row)
- Process the rows

Database Application workflow of Python program

- 1 Connect to the MySQL server
- 2 Connect to an existing database or create a new database
- 3 Write a Python interactive application with some user input
- 4 Execute a SQL query and fetch results
- 5 Print the results to end-user
- 6 Close the connection to the MySQL server

Connection to Database Server (MySQL Server)

- The *getpass* module is used to hide the password
- The *connect* object from ***mysql.connector*** module is used to establish the database connection
- *try* and *catch* statement is used to catch and print exceptions/errors to the database
- The *with* statement is used to taking care of closing the database connection. Leaving unused open connections can lead to several unexpected errors and performance issues
- The *input* is used for providing the user and password in order to **avoid** the *hardcoded login credentials.* More secure ways to store sensitive information is using *environment variables*

Python

```python
from getpass import getpass
from mysql.connector import connect, Error

try:
    with connect(
        host="localhost",
        user=input("Enter username: "),
        password=getpass("Enter password: "),
    ) as connection:
        print(connection)
except Error as e:
    print(e)
```

Connecting to an Existing Databases

- In most of the cases we already have created database using the DBMS and we only want to connect to it from our Python application
- We can do this the same connect() function by adding additional parameter called *database*, which is the name of database.

Python

```
from getpass import getpass
from mysql.connector import connect, Error

try:
    with connect(
        host="localhost",
        user=input("Enter username: "),
        password=getpass("Enter password: "),
        database="online_movie_rating",
    ) as connection:
        print(connection)
except Error as e:
    print(e)
```

Inserting Records in Tables (1)

- Using cursor.execute() method for inserting small number of records and the records can be hard-coded
- Use connection.commit() method to perform changes in the actual table.
- You can use many times the cursor.execute() method and in the end use **once** connection.commit() method to perform atomic transaction.
- Note! You don't need to add data for IDs as the AUTO_INCREMENT build in function automatically creates id values in database.
- **Note!** In MySQL, it's mandatory to put a semicolon (;) at the end of a statement, which denotes the termination of a query. However, MySQL Connector/Python automatically appends a semicolon at the end of your queries, so there's no need to have it in your Python code.

Python

```
insert_movies_query = """
INSERT INTO movies (title, release_year, genre, collection_in_mil)
VALUES
    ("Forrest Gump", 1994, "Drama", 330.2),
    ("3 Idiots", 2009, "Drama", 2.4),
    ("Eternal Sunshine of the Spotless Mind", 2004, "Drama", 34.5),
    ("Good Will Hunting", 1997, "Drama", 138.1),
    ("Skyfall", 2012, "Action", 304.6),
    ("Gladiator", 2000, "Action", 188.7),
    ("Black", 2005, "Drama", 3.0),
    ("Titanic", 1997, "Romance", 659.2),
    ("The Shawshank Redemption", 1994, "Drama",28.4),
    ("Udaan", 2010, "Drama", 1.5),
    ("Home Alone", 1990, "Comedy", 286.9),
    ("Casablanca", 1942, "Romance", 1.0),
    ("Avengers: Endgame", 2019, "Action", 858.8),
    ("Night of the Living Dead", 1968, "Horror", 2.5),
    ("The Godfather", 1972, "Crime", 135.6),
    ("Haider", 2014, "Action", 4.2),
    ("Inception", 2010, "Adventure", 293.7),
    ("Evil", 2003, "Horror", 1.3),
    ("Toy Story 4", 2019, "Animation", 434.9),
    ("Air Force One", 1997, "Drama", 138.1),
    ("The Dark Knight", 2008, "Action",535.4),
    ("Bhaag Milkha Bhaag", 2013, "Sport", 4.1),
    ("The Lion King", 1994, "Animation", 423.6),
    ("Pulp Fiction", 1994, "Crime", 108.8),
    ("Kai Po Che", 2013, "Sport", 6.0),
    ("Beasts of No Nation", 2015, "War", 1.4),
    ("Andadhun", 2018, "Thriller", 2.9),
    ("The Silence of the Lambs", 1991, "Crime", 68.2),
    ("Deadpool", 2016, "Action", 363.6),
    ("Drishyam", 2015, "Mystery", 3.0)
"""
with connection.cursor() as cursor:
    cursor.execute(insert_movies_query)
    connection.commit()
```

Inserting Records in Tables (2)

- Using cursor.executemany() method when the data are stored in file or generated by a different script.
- It takes two parameters:
  - A **query** string
  - A **list** with records to be inserted
- The code uses %s as a placeholder for the two strings that had to be inserted in the query string
- Placeholders act as format specifiers and help reserve a spot for a variable inside a string. The specified variable is then added to this spot during execution.

Python

```
insert_reviewers_query = """
INSERT INTO reviewers
(first_name, last_name)
VALUES ( %s, %s )
"""
reviewers_records = [
    ("Chaitanya", "Baweja"),
    ("Mary", "Cooper"),
    ("John", "Wayne"),
    ("Thomas", "Stoneman"),
    ("Penny", "Hofstadter"),
    ("Mitchell", "Marsh"),
    ("Wyatt", "Skaggs"),
    ("Andre", "Veiga"),
    ("Sheldon", "Cooper"),
    ("Kimbra", "Masters"),
    ("Kat", "Dennings"),
    ("Bruce", "Wayne"),
    ("Domingo", "Cortes"),
    ("Rajesh", "Koothrappali"),
    ("Ben", "Glocker"),
    ("Mahinder", "Dhoni"),
    ("Akbar", "Khan"),
    ("Howard", "Wolowitz"),
    ("Pinkie", "Petit"),
    ("Gurkaran", "Singh"),
    ("Amy", "Farah Fowler"),
    ("Marlon", "Crafford"),
]
with connection.cursor() as cursor:
    cursor.executemany(insert_reviewers_query, reviewers_records)
    connection.commit()
```

Inserting Records in Tables (3)

Note! We use sting placeholder %s for any data type

Note! The Python program should check if the data type of the values are correct for the database

Python

```
insert_ratings_query = """
INSERT INTO ratings
(rating, movie_id, reviewer_id)
VALUES ( %s, %s, %s)
"""
ratings_records = [
    (6.4, 17, 5), (5.6, 19, 1), (6.3, 22, 14), (5.1, 21, 17),
    (5.0, 5, 5), (6.5, 21, 5), (8.5, 30, 13), (9.7, 6, 4),
    (8.5, 24, 12), (9.9, 14, 9), (8.7, 26, 14), (9.9, 6, 10),
    (5.1, 30, 6), (5.4, 18, 16), (6.2, 6, 20), (7.3, 21, 19),
    (8.1, 17, 18), (5.0, 7, 2), (9.8, 23, 3), (8.0, 22, 9),
    (8.5, 11, 13), (5.0, 5, 11), (5.7, 8, 2), (7.6, 25, 19),
    (5.2, 18, 15), (9.7, 13, 3), (5.8, 18, 8), (5.8, 30, 15),
    (8.4, 21, 18), (6.2, 23, 16), (7.0, 10, 18), (9.5, 30, 20),
    (8.9, 3, 19), (6.4, 12, 2), (7.8, 12, 22), (9.9, 15, 13),
    (7.5, 20, 17), (9.0, 25, 6), (8.5, 23, 2), (5.3, 30, 17),
    (6.4, 5, 10), (8.1, 5, 21), (5.7, 22, 1), (6.3, 28, 4),
    (9.8, 13, 1)
]
with connection.cursor() as cursor:
    cursor.executemany(insert_ratings_query, ratings_records)
    connection.commit()
```

Reading Records From the Database (1)

- Create SELECT query string
- Use cursor.fetchall() method to extract the records
- It returns a list of tuples representing individual records from the table
- Tuple is ordered collection of objects, they are defined by enclosing the elements in parentheses () instead of square brackets. And they are immutable (read-only).
- Use the LIMIT clause with (offset,max) to constrain the number of rows that are received from the SELECT statement. And to provide the pagination when handling large volumes of data.

```
Python                                                                    >>>
>>> select_movies_query = "SELECT * FROM movies LIMIT 5"
>>> with connection.cursor() as cursor:
...     cursor.execute(select_movies_query)
...     result = cursor.fetchall()
...     for row in result:
...         print(row)
...
(1, 'Forrest Gump', 1994, 'Drama', Decimal('330.2'))
(2, '3 Idiots', 2009, 'Drama', Decimal('2.4'))
(3, 'Eternal Sunshine of the Spotless Mind', 2004, 'Drama', Decimal('34.5'))
(4, 'Good Will Hunting', 1997, 'Drama', Decimal('138.1'))
(5, 'Skyfall', 2012, 'Action', Decimal('304.6'))
```

LIMIT 5 means only the first 5 records are fetched

limit = 5
“””…. LIMIT {0},{1};”””.format(offset,limit)
…..
If button_next_click:
  offset + =1 //increase the offset

Reading Records From the Database (2)

```
planetName = input("Provide a planet name: ")
cursor.execute("SELECT * FROM planets WHERE name = '%s'" % planetName)
planet_details = cursor.fetchall()
print(planet_details)
```

Printing Tuples list as Table in Python

Printing tuples as table

```
list_el = [('element1', 'element2', 'element3'),
           ('elementelel4', 'element5', 'elementelement'),
           ('el7', 'el8', 'elel9')]

row = "{name1:^20}|{name2:^20}|{name3:^20}".format
for tup in list_el:
    print(row(name1=tup[0], name2=tup[1], name3=tup[2]))
```

Output:

```
  element1      |      element2      |      element3
elementelel4    |      element5      |   elementelement
    el7         |        el8         |       elel9
```

Functions to map data structure from database structure to Python data structure and vise versa

```
def tuples_to_dict(list_tuples,column_names):
    list_dict = []
    for tuple in list_tuples:
        dict = {}
        dict[column_names[0]] = tuple[0]
        dict[column_names[1]] = tuple[1]
        dict[column_names[2]] = tuple[2]
        list_dict.append(dict)
    return  list_dict


def dict_to_tuples(list_dict):
    list_tuples = []
    for item in list_dict:
        list_tuples.append(tuple(item.values()))
    return   list_tuples


list_tuples = [('element1','element2','element3'),('element5','element6','element7'),
column_names = ["first_name","last_name","birthday"]

my_list = tuples_to_dict(list_tuples,column_names)
print(my_list)

my_tuples = dict_to_tuples(my_list)
print(my_tuples)
```

Filtering Results Using the WHERE Clause

Python >>>

```
>>> select_movies_query = """
... SELECT title, collection_in_mil
... FROM movies
... WHERE collection_in_mil > 300
... ORDER BY collection_in_mil DESC
... """
>>> with connection.cursor() as cursor:
...     cursor.execute(select_movies_query)
...     for movie in cursor.fetchall():
...         print(movie)
...
('Avengers: Endgame', Decimal('858.8'))
('Titanic', Decimal('659.2'))
('The Dark Knight', Decimal('535.4'))
('Toy Story 4', Decimal('434.9'))
('The Lion King', Decimal('423.6'))
('Deadpool', Decimal('363.6'))
('Forrest Gump', Decimal('330.2'))
('Skyfall', Decimal('304.6'))
```

```
height = int(input("Provide a height: "))
cursor.execute("SELECT name FROM species WHERE average_height>%s", (height,))
planets_with_height = cursor.fetchall()
print(plantes_with_height)
```

Updating Records From the Database

Python

```
update_query = """
UPDATE
    reviewers
SET
    last_name = "Cooper"
WHERE
    first_name = "Amy"
"""
with connection.cursor() as cursor:
    cursor.execute(update_query)
    connection.commit()
```

Note: In the UPDATE query, the WHERE clause helps specify the records that need to be updated. If you don't use WHERE, then all records will be updated!

Python

```
from getpass import getpass
from mysql.connector import connect, Error

movie_id = input("Enter movie id: ")
reviewer_id = input("Enter reviewer id: ")
new_rating = input("Enter new rating: ")
update_query = """
UPDATE
    ratings
SET
    rating = "%s"
WHERE
    movie_id = "%s" AND reviewer_id = "%s";

SELECT *
FROM ratings
WHERE
    movie_id = "%s" AND reviewer_id = "%s"
""" % (
    new_rating,
    movie_id,
    reviewer_id,
    movie_id,
    reviewer_id,
)

try:
    with connect(
        host="localhost",
        user=input("Enter username: "),
        password=getpass("Enter password: "),
        database="online_movie_rating",
    ) as connection:
        with connection.cursor() as cursor:
            for result in cursor.execute(update_query, multi=True):
                if result.with_rows:
                    print(result.fetchall())
            connection.commit()
except Error as e:
    print(e)
```

Deleting Records From the Database

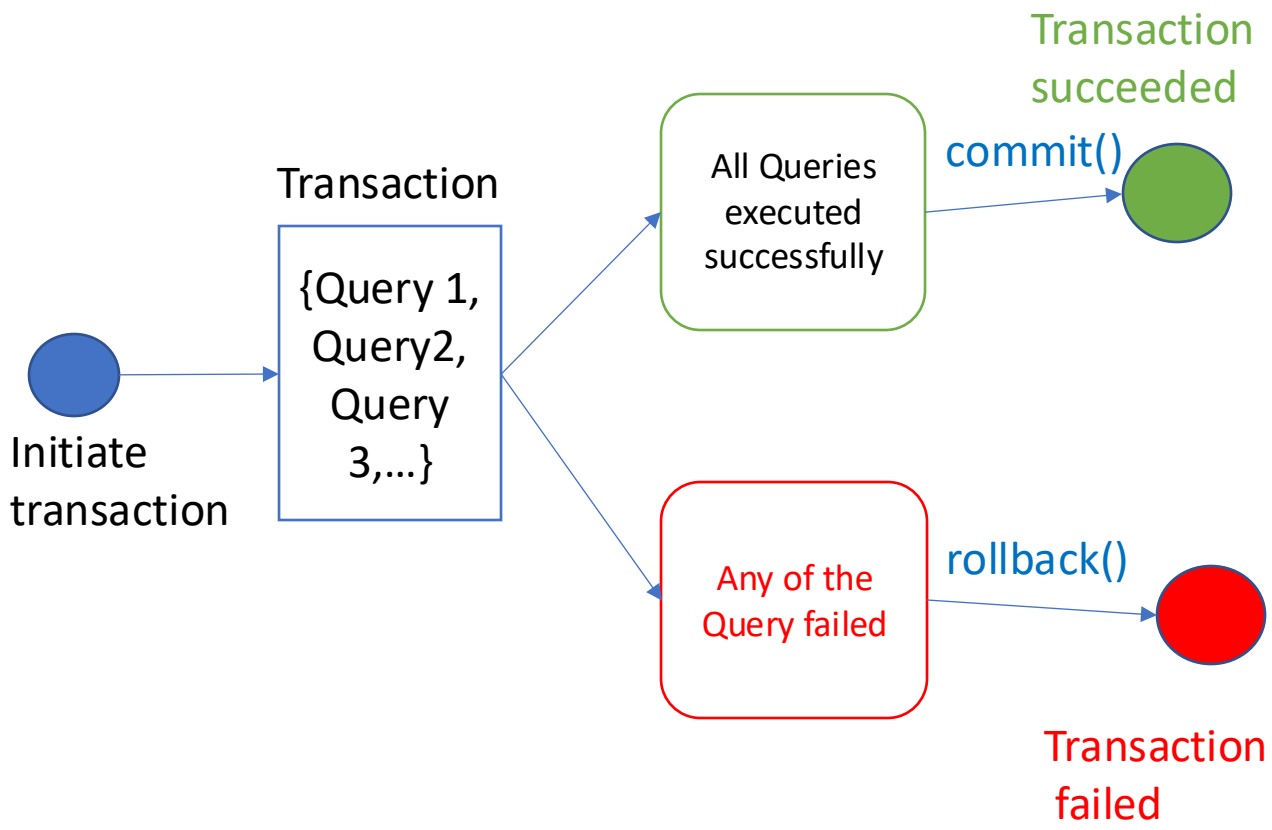
Python

```
delete_query = "DELETE FROM ratings WHERE reviewer_id = 2"
with connection.cursor() as cursor:
    cursor.execute(delete_query)
    connection.commit()
```

Note: Deleting is an *irreversible* process. If you don't use the WHERE clause, then all records from the specified table will be deleted. You'll need to run the INSERT INTO query again to get back the deleted records.

Commit & Rollback Operation to manage transactions in Python

- The commit() method is used to make sure the changes made to the database are consistent
  - Syntax: connection.commit()
- The rollback() method is used to revert the last changes made to the database when one of the query failed.
  - Syntax: connection.rollback()



Example

```
import mysql.connector

try:
    conn = mysql.connector.connect(host='localhost',
                                   database='python_db',
                                   user='pynative',
                                   password='pynative@#29')

    conn.autocommit = False
    cursor = conn.cursor()
    # withdraw from account A
    sql_update_query = """Update account_A set balance = 1000 where id = 1"""
    cursor.execute(sql_update_query)

    # Deposit to account B
    sql_update_query = """Update account_B set balance = 1500 where id = 2"""
    cursor.execute(sql_update_query)
    print("Record Updated successfully ")

    # Commit your changes
    conn.commit()

except mysql.connector.Error as error:
    print("Failed to update record to database rollback: {}".format(error))
    # reverting changes because of exception
    conn.rollback()
finally:
    # closing database connection.
    if conn.is_connected():
        cursor.close()
        conn.close()
        print("connection is closed")
```

Do not hard code the user credentials!
You can do it only in development mode

Recommendations for Assignment 2

- Save passwords encrypted in the database
- Use regular expressions for checking user input (use *re* library in Python)
- The application must be a multi-user application where customers making order simultaneously, ensure that customer get access to his/her order and not to someone else order.

References

Python and MySQL Database: A Practical Introduction: Web URL

Use Commit and Rollback to Manage MySQL Transactions in Python: https://pynative.com/python-mysql-transaction-management-using-commit-rollback/