CS50's Web Programming with Python and JavaScript

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ORMs, APIs

Object-Oriented Programming

- Python, along with many other programming langauges, use Object-Oriented Programming (OOP). An 'object' is a discrete item. OOP allows for the creation of classes, which are the generic forms of objects. For example, a 'flight' class is defines all the components which describe a flight, as well as actions that a flight should be able to take, such as adding a passenger. Similarly, a passenger class would represent the generic idea of passenger, defined by a name and associated with a flight, perhaps.
- Here's a simple example of a Python class.

```
class Flight:

    def __init__(self, origin, destination, duration):
        self.origin = origin
        self.destination = destination
        self.duration = duration
```

  - `__init__` is a 'method', which is a function performed on individual objects. `__init__` in particular is a special, built-in method that describes what should happen when a flight object is created.
  - Generally, methods take `self` as their first argument. `self` refers to the object being worked with. The other three arguments are simply the information that should be stored about a particular flight. That information is stored as 'properties' inside the object, using dot notation.
- Here's how the `Flight` class might be used:

```
# Create flight.
f = Flight(origin="New York", destination="Paris", duration=540)

# Change the value of a propety.
f.duration += 10

# Print details about flight.
print(f.origin)
print(f.destination)
print(f.duration)
```

  - Note that only flight information is passed in to `Flight()`; the `self` argument to the `__init__` method is automatically specified.
  - `f` is a variable of type `Flight`, just like a variable might be of type `str` or `int`.

- Additional methods can be added to the `Flight class` :

```
class Flight:

    # assume same __init__ method

    def print_info(self):
        print(f"Flight origin: {self.origin}")
        print(f"Flight destination: {self.destination}")
        print(f"Flight duration: {self.duration}")

def main():
    f1 = Flight(origin="New York", destination="Paris", duration=540)
    f1.print_info()
```

  - Now, this functionality of printing out flight info can be used with any flight object that might be created. Each time, `self` refers to the object that the method is being called on. In this example, that's `f1` .

- Methods can also take additional arguments and modify properties.

```
def delay(self, amount):
    self.duration += amount
```

  - Note that writing methods like `delay` and `print_info` , as well just the idea of `Flight` class in general, allow for abstraction. The `Flight` class and all of its methods can be used in a logical and easily understood way without needing to know or even understand how `Flight` may be implemented.

- Given a simple `Passenger` class...

```
class Passenger:

    def __init__(self, name):
        self.name = name
```

- A more complex `Flight` class can be implemented.

```
class Flight:

    counter = 1

    def __init__(self, origin, destination, duration):

        # Keep track of id number.
        self.id = Flight.counter
        Flight.counter += 1

        # Keep track of passengers.
        self.passengers = []

        # Details about flight.
        self.origin = origin
        self.destination = destination
        self.duration = duration

    def print_info(self):
        print(f"Flight origin: {self.origin}")
        print(f"Flight destination: {self.destination}")
        print(f"Flight duration: {self.duration}")

        print()
        print("Passengers:")
        for passenger in self.passengers:
            print(f"{passenger.name}")

    def add_passenger(self, p):
        self.passengers.append(p)
        p.flight_id = self.id
```

  - Note that `counter` is defined outside of the `__init__` function and is not specific to individual flights (it's not defined as `self.counter` . This means that all flight objects can see this same counter variable, which allows for the implementation the `id` property shown here. Similar to the SQL database which had an auto-incrementing `id` column, the `id` property of flights will automatically incrememt as new flight objects are created.
  - The `passengers` property of `Flights` is going to be a list of `Passenger` objects.
  - In `add_passenger` , `p.flight_id` is created, because `flight_id` is not defined in the `Passenger` class's `__init__` .

- Here's how the more advanced `Flight` class could be used:

```
# Create flight.
f1 = Flight(origin="New York", destination="Paris", duration=540)

# Create passengers.
alice = Passenger(name="Alice")
bob = Passenger(name="Bob")

# Add passengers.
f1.add_passenger(alice)
f1.add_passenger(bob)

f1.print_info()
```

Object Relational Mapping

- Object-Relational Mapping, or ORM, allows for the combination of the OOP world of Python and the relational database world of SQL. With ORM, Python classes, methods, and objects become the tools for interacting with SQL databases. To do this, the Flask-SQLAlchemy package will be used.
- The basic setup, inside `models.py` :

```
from flask_sqlalchemy import SQLAlchemy

db = SQLAlchemy()

class Flight(db.Model):
    __tablename__ = "flights"
    id = db.Column(db.Integer, primary_key=True)
    origin = db.Column(db.String, nullable=False)
    destination = db.Column(db.String, nullable=False)
    duration = db.Column(db.Integer, nullable=False)


class Passenger(db.Model):
    __tablename__ = "passengers"
    id = db.Column(db.Integer, primary_key=True)
    name = db.Column(db.String, nullable=False)
    flight_id = db.Column(db.Integer, db.ForeignKey("flights.id"), nullable=False)
```

  - For any table inside of the database, there is one class defined inside `models.py` .
  - Adding `db.Model` in parentheses after class names indicates that these classes 'inherit' from `db.Model` . The details of inheritance are unimportant right now; simply, this allows for the class to have some built-in relationship with SQLAlchemy to interact with the database.
  - `__tablename__` naturally corresponds with the table name inside the database.
  - Every property is defined as a `db.Column` , which will become columns in the table. The arguments to `db.Column` are naturally similar to those use for table creation in SQL.
  - Note that `flights.id` is marked as a foreign key using the `__tablename__` `flights` , not the class name `Flight` .
- Now that there's a defined structure for how the tables should look, they can be created inside a Flask application.

```
import os

from flask import Flask, render_template, request

# Import table definitions.
from models import *

app = Flask(__name__)

# Tell Flask what SQLAlchemy databas to use.
app.config["SQLALCHEMY_DATABASE_URI"] = os.getenv("DATABASE_URL")
app.config["SQLALCHEMY_TRACK_MODIFICATIONS"] = False

# Link the Flask app with the database (no Flask app is actually being run yet).
db.init_app(app)

def main():
    # Create tables based on each table definition in `models`
    db.create_all()

if __name__ == "__main__":
    # Allows for command line interaction with Flask application
    with app.app_context():
        main()
```

Python Versions of SQL Queries

- `db.create_all()` is the Python-Flask-SQLAlchemy's version of the `CREATE` SQL command.

- SQL's `INSERT` ...

```
INSERT INTO flights
    (origin, destination, duration)
    VALUES ('New York', 'Paris', 540)
```

- ...and Python's `INSERT` .

```
flight = Flight(origin="New York", destination="Paris", duration=540)
db.session.add(flight)
```

  - SQlAlchemy automatically takes care of SQL transactions with `db.session` .

- SQL's `SELECT` ...

```
SELECT * FROM flights;
SELECT * FROM flights
    WHERE origin = 'Paris';
SELECT * FROM flights
    WHERE origin = 'Paris' LIMIT 1;
SELECT COUNT(*) FROM flights
    WHERE origin = 'Paris';
SELECT * FROM flights WHERE id = 28;
SELECT * FROM flights
    ORDER BY origin;
SELECT * FROM flights
    ORDER by origin DESC;
SELECT * FROM flights
    WHERE origin != 'Paris';
SELECT * FROM flights
    WHERE origin LIKE '%a%';
SELECT * FROM flights
    WHERE origin IN ('Tokyo', 'Paris');
SELECT * FROm flights
    WHERE origin = "Paris"
    AND duration > 500;
SELECT * FROm flights
    WHERE origin = "Paris"
    AND duration > 500;
SELECT * FROM flights JOIN passengers
    ON flights.id = passengers.flight_id;
```

- ...and Python's `SELECT` :

```
Flight.query.all()
Flight.query.fliter_by(origin="Paris").all()
Flight.query.filter_by(origin="Paris").first()
Flight.query.filter_by(origin="Paris").count()
Flight.query.get(28)
Flight.query.order_by(Flight.origin).all()
Flight.query.order_by(Flights.origin.desc()).all()
Flight.query.filter(Flight.origin != "Paris").all()
Flight.query.filter(Flight.origin.like("%a%")).all()
Flight.query.filter(Flight.origin.in_(["Tokyo", "Paris"])).all()
Flight.query.filter(and_(Flight.origin == "Paris", Flight.duration > 500)).all()
Flight.query.filter(or_(Flight.origin == "Paris", Flight.duration > 500)).all()
db.session.query(Flight, Passenger).filter(Flight.id == Passenger.flight_id).all()
```

- SQL's `UPDATE` ...

```
UPDATE flights SET duration = 280
    WHERE id = 6;
```

- ...and Python's `UPDATE` :

```
flight = Flight.query.get(6)
flight.duration = 280
```

- SQL's `DELETE` ...

```
DELETE FROM flights WHERE id = 28;
```

- ...and Python's `DELETE` :

```
flight = Flight.query.get(28)
db.ksession.delete(flight)
```

- Some other miscellaneous SQL commands...

```
COMMIT;
```

- ...and their Python parallels.

```
db.session.commit()
```

- Before, when importing data from a CSV file, SQL code had to be written directly into the Python file. Now, SQLAlchemy can take care of that behind the scenes.

```
import csv

# Same setup code as before.

def main():
    f = open("flights.csv")
    reader = csv.reader(f)
    for origin, destination, duration in reader:
        flight = Flight(origin=origin, destination=destination, duration=duration)
        db.session.add(flight)
        print(f"Added flight from {origin} to {destination} lasting {duration} minutes.")
    db.session.commit()
```

ORM Integrated into a Web Application

- Putting it all together, here's the same web application from the end of Lecture 3, using SQLAlchemy. Note that there are no raw SQL commands. The power of ORM, classes, and objects is used to insert and select from the database.

```
from flask import Flask, render_template, request
from models import *

app = Flask(__name__)
app.config["SQLALCHEMY_DATABASE_URI"] = os.getenv("DATABASE_URL")
app.config["SQLALCHEMY_TRACK_MODIFICATIONS"] = False
db.init_app(app)


@app.route("/")
def index():
    flights = Flight.query.all()
    return render_template("index.html", flights=flights)


@app.route("/book", methods=["POST"])
def book():
    """Book a flight."""

    # Get form information.
    name = request.form.get("name")
    try:
        flight_id = int(request.form.get("flight_id"))
    except ValueError:
        return render_template("error.html", message="Invalid flight number.")

    # Make sure the flight exists.
    flight = Flight.query.get(flight_id)
    if flight is None:
        return render_template("error.html", message="No such flight with that id.")

    # Add passenger.
    passenger = Passenger(name=name, flight_id=flight_id)
    db.session.add(passenger)
    db.session.commit()
    return render_template("success.html")


@app.route("/flights")
def flights():
    """List all flights."""
    flights = Flight.query.all()
    return render_template("flights.html", flights=flights)


@app.route("/flights/<int:flight_id>")
def flight(flight_id):
    """List details about a single flight."""

    # Make sure flight exists.
    flight = Flight.query.get(flight_id)
    if flight is None:
        return render_template("error.html", message="No such flight.")

    # Get all passengers.
    passengers = Passenger.query.filter_by(flight_id=flight_id).all()
    return render_template("flight.html", flight=flight, passengers=passengers)
```

- Because classes are flexible, whatever additional functionality the app may need can be built into classes. Adding passengers, for example, can be defined as a method in the `Flight` class (in `models.py`).

```
def add_passenger(self, name):
    p = Passenger(name=name, flight_id=self.id)
    db.session.add(p)
    db.session.commit()
```

- Now, after verifying that the flight exists, the all that is needed in the `book` function of `application.py` is the following:

```
flight.add_passenger(name)
```

    - Now, there is on direct creation of passengers in the application. It's all handled by the `Flight` class.

Relationships

- One more powerful feature of ORMs is the idea of relationships. SQLAlchemy relationships are an easy way to take one table and relate it to another table, such that the each can refer to the other. A relationship is set up with a single line, which in this case would be added to the definition of the `Flight` class.

```
passengers = db.relationship("Passenger", backref="flight", lazy=True)
```

- `passengers` is not a column, but rather just a relationship. Given a flight object, the `passengers` property can be used to extract all the passenger info for that flight.
- `backref` creates a relationship in the opposite direction, from `Flight` to `Passenger`.
- `lazy` indicates that the information should be fetched only when it's asked for.k

- With these relationships set up, the code in `application.py`'s `flight` function to list get all passengers is extremely simplified.

```
passengers = flight.passengers
```

- Once again, SQL's `SELECT` ...

```
SELECT * FROM passengers
    WHERE flight_id = 1
SELECT * FROM flights JOIN passengers
    ON flights.id = passengers.flight_id
    WHERE passengers.name = 'Alice';
```

- ...and Python's relationship-powered `SELECT`.

```
Flight.query.get(1).passengers
Passenger.query.filter_by(name="Alice").first().flight
```

APIs

- An Application Programming Interface, or API, is a protocol for communication between different web applications or different components of the same application. These different components will want to share information with each other or perform actions on other spaces, and APIs allow for this interaction. It is useful, then, to have a standard language for how this communication will occur.

JSON

- One such language is Javascript Object Notation (JSON), which is a simple way of representing information in human- and computer-readable way so that it can be passed between parts of web application.
- Some example JSON:

```
{
    "origin" : {
        "city": "Tokyo",
        "code": "HND"
    },
    "destination": {
        "city": "Shanghai",
        "code": "PVG"
    },
    "duration" : 185,
    "passengers" : ["Alice", "Bob"]
}
```

    - The curly braces enclose a JSON object.
    - The contets of the JSON object are dvided into key-value pairs.
    - `origin` and `duration` are themselves JSON objects, which are nested in a hierarchical structure.
    - `passengers` shows how lists can be values.
- Often times, the interaction between two APIs happens through the URL, which specifics which particular information that should be accessed. Some different levels might be:

```
/flights/
/flights/28/
/flights/28/passengers/
/flights/28/passengers/6/
```

HTTP Methods

- Often times, there are different ways an API can be used. For example, one might get information about a passenger, register a new passenger, or change registration information for a flight.
- The HTTP request method will correspond to the type of action that should be performed. This is simply a convention that many APIs follow. Some HTTP methods include:
    - `GET`: retrieve a resource

- `POST` : create a new resource
- `PUT` : replace a resource
- `PATCH` : update a resource
- `DELETE` : delete a resource

- The Python Requests library allows for all these different HTTP methods to be used.

```
import requests

def main():
    res = requests.get("https://www.google.com/")
    print(res.text)
```

```
* `res` (response) is the HTTP response that comes from submitting, in this case, a `GET` request to a URL. All the following are als
    * `requests.post(url)`
    * `requests.put(url)`
    * `requests.patch(url)`
    * `requests.delete(url)`
* `res.text` is the HTML content of the page that is returned from the request.
```

An Example API

- To demonstrate the potential for these requests, Fixer (https://fixer.io), a foreign exchange rate API, will be used in the following examples.
- Accessing the API at the URL http://data.fixer.io/api/latest?access_key=apikey&base=EUR&symbols=USD' returns the following JSON:

```
{
    "success": true,
    "timestamp": 1519296206,
    "base": "EUR",
    "date": "2018-07-11",
    "rates": {
        "USD": 1.177482
    }
}
```

- This API can be accessed in Python using the Requests library.

```
res = requests.get("http://data.fixer.io/api/latest?access_key=apikey&base=EUR&symbols=USD")
if res.status_code != 200:
    raise Exception("ERROR: API request unsuccessful.")
data = res.json()
print(data)
```

```
* Checking the status code of the HTTP response ensures that the API returned what is expected by the application (a JSON formatted 1
    * `200 OK`
    * `201 Created`
    * `400 Bad Request`
    * `403 Forbidden`
    * `404 Not Found`
    * `405 Method Not Allowed`
    * `422 Unprocessable Entity`
* `res.json()` simply extracts the JSON response and puts into the Python variable `data`.
```

- The previous returned the entire, raw JSON returned by the API. Since the format of the JSON is consistent and known, the most relevant information can be extracted and displayed.

```
rate = data["rates"]["USD"]
print(f"1 EUR is equal to {rate} USD")
```

- For a little more flexibility on what currencies are being converted, user input can be taken like so:

```
base = input("First Currency: ")
other = input("Second Currency: ")
res = requests.get("http://data.fixer.io/api/latest",
                   params={"access_key": apikey, "base": base, "symbols": other})
```

  - What parameters should be passed into `params` (in this case, `"access_key"`, `"base"` and `"symbols"`) are defined in the API documentation.

Creating an API

- To implement an API for the recurring example of a airline flight manager, all that needs to be done is to define a route that returns a JSON object, just like Fixer does.

```python
from flask import Flask, render_template, jsonify, request

# ... other imports, set up code, and routes ...

@app.route("/api/flights/<int:flight_id>")
def flight_api(flight_id):
    """Return details about a single flight."""

    # Make sure flight exists.
    flight = Flight.query.get(flight_id)
    if flight is None:
        return jsonify({"error": "Invalid flight_id"}), 422

    # Get all passengers.
    passengers = flight.passengers
    names = []
    for passenger in passengers:
        names.append(passenger.name)
    return jsonify({
            "origin": flight.origin,
            "destination": flight.destination,
            "duration": flight.duration,
            "passengers": names
        })
```

- The route URL is clearly marked as an API, and takes any flight ID as a parameter.
- `jsonify` is a function provided by Flask that takes in a Python dictionary and converts it into JSON.
- If there is no flight found, an HTTP status code (422) is also returned with the JSON to indicate an error has occurred.
- Seen here again is the readability and simplicity of relationships when retrieving passenger information.
- If a valid flight ID was passed as a parameter, then a JSON object with all the flight info and a list of passengers is returned (because no status code is specified, it is set to 200 by default).

API Keys

- With larger APIs, an often-implemented feature is rate limiting. It is undesirable to have users making a large number of requests that might overload the API or make it harder for other users to access it. To restrict access, users must first obtain an API key (a long string) which must be provided with any API request. Keys allow for the tracking of individual users only allowing, for example, 100 requests per hour per user.