System Design problems

**SOLID OOD Principal:**

**S**– **S**ingle Responsibility Principle | Single responsibility to each Object

**O**– **O**pen/Closed Principal  | On production level Objects are ready for extension for not for modification

**L**–**L**iskov Substitution Principal | Base Class and Derived class follow ‘IS A’ principal

**I** – **I**nterface segregation principle | If an implementation don’t require then don’t implement it.

**D-D**ependency Inversion principle | Reduce the dependency In composition of objects.

General Steps For OOD System Design:

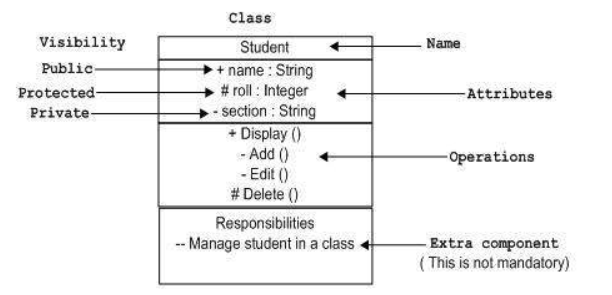
Now, here are some steps to follow to answer an object-oriented design question like design an object-oriented parking lot.

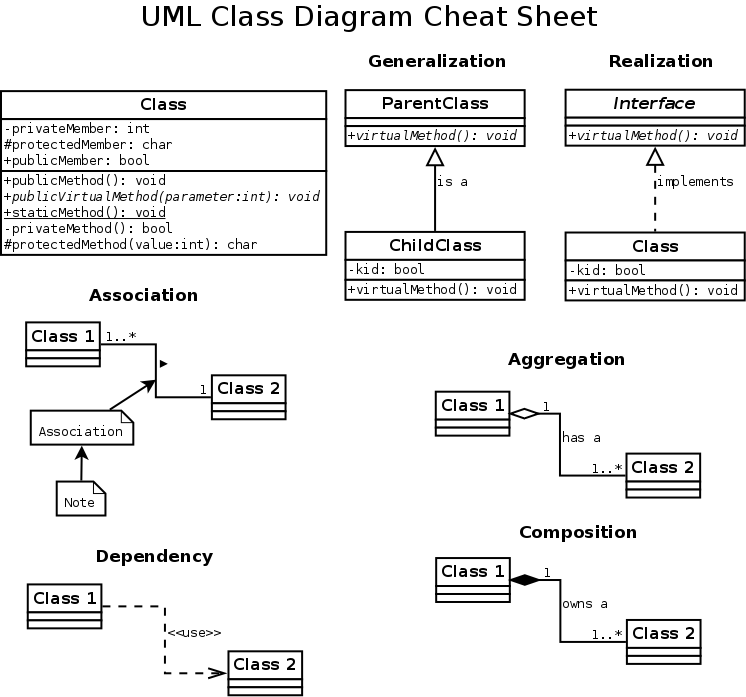
1. Identify the **major entities** like vehicles, parking spaces, parking structure and so on using interfaces.
2. Identify **specialized subtypes of these entities** using abstract classes or just regular classes. For example, your parking spaces may be of different types, two-wheeler parking spots, car parking spots, handicapped parking spots and so on.
3. Determine the **functionality(behaviour)** of each of these entities, such as a car should have a license plate, and have the ability to move; a parking structure should be able to tell you the next available spot to park; a parking space should be able to keep track of your cost of parking and so on.
4. Determine the functionality of specialized entities. All parking spaces have same properties like indicating whether they are occupied or not, and calculating the cost of parking your vehicle but two wheeler spots are cheaper than four wheeler spots.
5. **Setup relationships between entities** that communicate with each other. Parking space and parking structure can be connected association, that is a parking structure has many parking spaces, and of different types.
6. Lastly, to make yourself standout, **use design patterns where appropriate**. The most obvious scenario is, obviously not everyone should be able to create their own parking structure on the fly. Make it a singleton class so there is only parking structure, and vehicle owners will use it using your public methods.

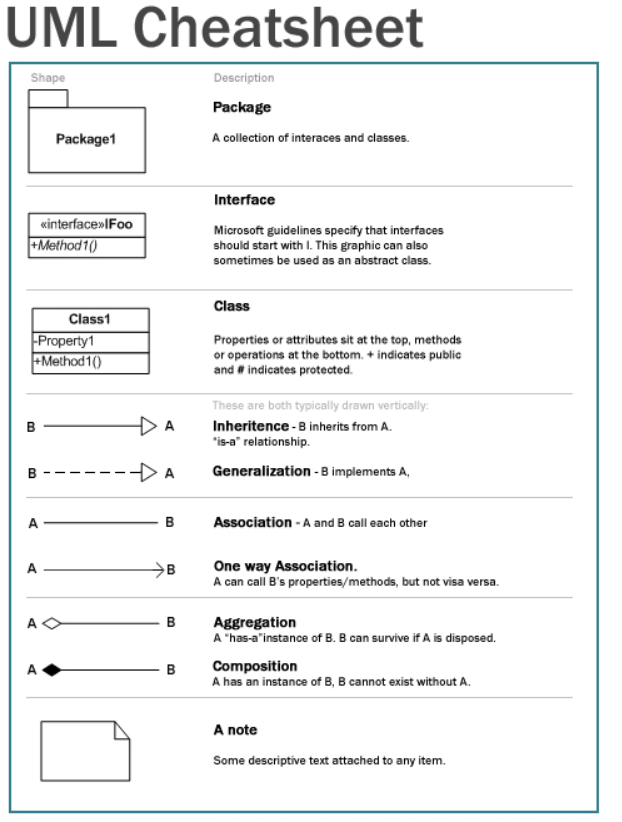
Steps for System Design in general:

1. Get the system details, requirements. Ask clarifying questions, features…
2. First write down/sketch a high-level system design - architecture, big picture. Don’t dive into technical details. Just high-level design – LB, servers, DB, caching, scalability etc
3. Low level system design: DB schema, UML diagrams, OOD class and relationships, API design, etc

UML Notations:







Technical concepts

1)Data Warehouse VS Database:

* A database designed to handle transactions isn’t designed to handle analytics. It isn’t structured to do analytics well.
* A data warehouse, on the other hand, is structured to make analytics fast and easy.
* A data warehouse exists as a layer on top of another database or databases (usually OLTP databases). The data warehouse takes the data from all these databases and creates a layer optimized for and dedicated to analytics.

2) Kafka:

**Apache Kafka** is an [open-source](https://en.wikipedia.org/wiki/Open_source) [stream processing](https://en.wikipedia.org/wiki/Stream_processing) software platform developed by the [Apache](https://en.wikipedia.org/wiki/Apache_Software_Foundation).

The project aims to provide a unified, high-throughput, low-latency platform for handling real-time data feeds

Publish and subscribe - Read and write streams of data like a messaging system.

What is Kafka good for?

It gets used for two broad classes of application:

1. Building real-time streaming data pipelines that reliably get data between systems or applications
2. Building real-time streaming applications that transform or react to the streams of data

**1) Elevator design**

Ask possible questions about the entities – about elevator, its building, no of ppl, floors, features, buttons etc

Entities: Elevator, User, Button, ElevatorController, States, Building.

User

• Presses the floor button to call the lift

• Presses the elevator button to move to the desired floor

Floor Button & Elevator Button

• Illuminates when pressed by user

• Places an elevator request when pressed

Elevator

• Moves up/down as per instruction

• Opens/closes the door

ElevatorController

* Centralized control for elevators
* Will have a queue for requests from users
* Will dispatch the request to nearest lift using some scheduling algorithms

State

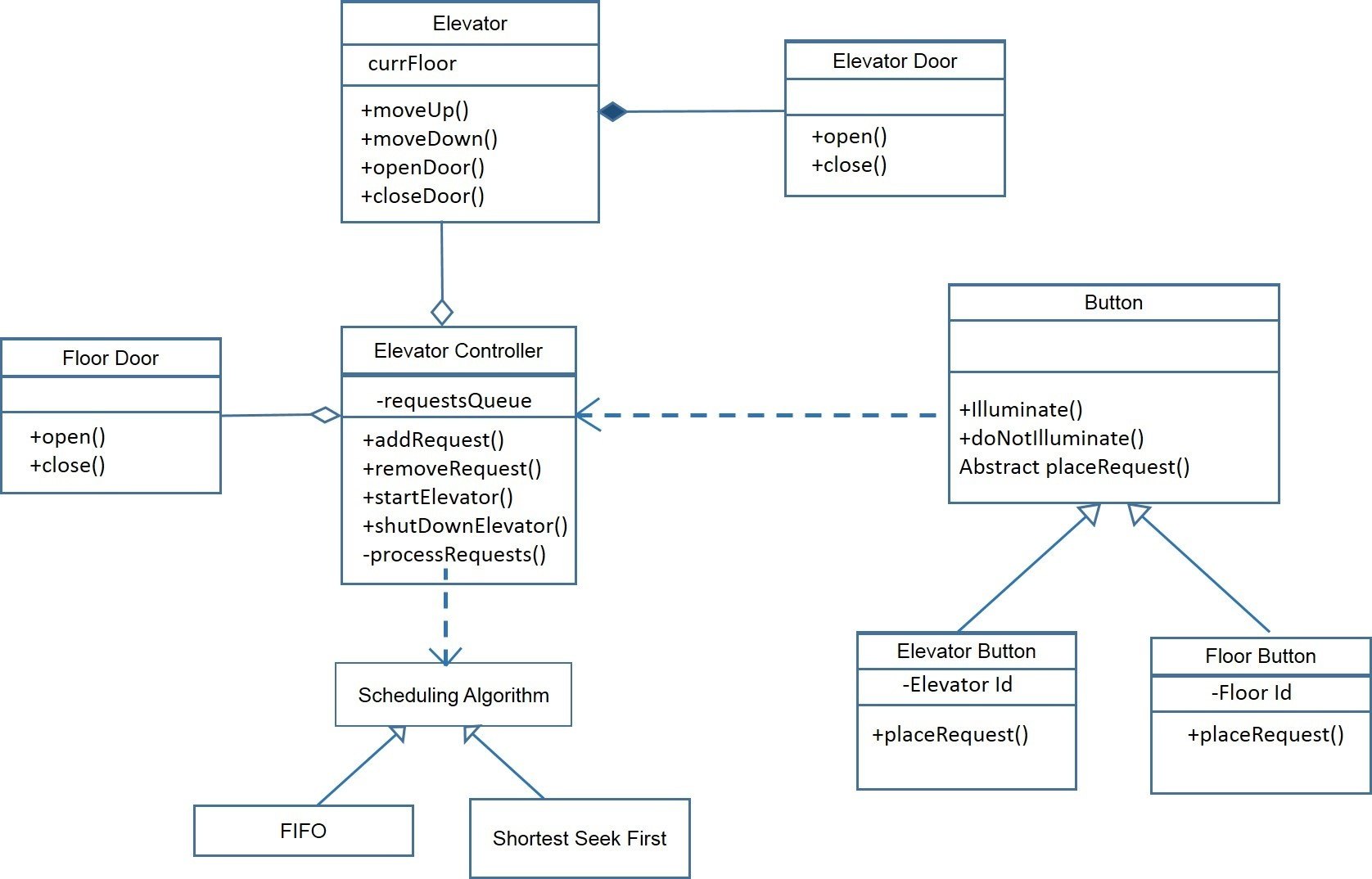
* Idle
* Going UP
* Going Down
* DoorOpening
* DoorClosing
* Beeping

Inheritance…

* Create interface IElevator – methods like goUP, goDown, Opendoors, closeDoors..
* Create an abstract class BaseElevator … all properties , general method definitions…abstract method handlerequest()..
* Create specific Elevator implementations like PassengerLift, ServiceLift… They will extend BaseElevator and implement IElevator..
* IEventController…interface

Design:

1. Each button press results in an elevator request which has to be served. Each of these requests is tracked at a centralized place. Elevator Requests, the class that stores, elevator requests can use different algo to schedule the elevator requests. The elevator is managed by a controller class, which we call Elevator Controller. Elevator controller class provide instructions to the elevator. Elevator controller reads the next elevator request to be processed and served.
2. The button is an abstract class defining common behavior like illuminate, doNotIlluminate. FloorButton, Elevator Button extends Button type and define placeRequest() method which is invoked when a button is pressed.
3. When a floor button or elevator button is presses a requests is added to a common queue.ElevatorController reads the next request and instruct next action to the elevator.
4. FloorButton's placeRequest() adds a request to the common queue, which is accessed by the elevator controller thereby assigning the request to one of the elevators.
5. ElevatorButton's placeRequest adds a request to the elevator directly as it is supposed to serve it.
6. Elevator controller will be running various algorithms like shortest seek etc. to decide which lift is supposed to handle which request.



Algorithm:

But in the simple steps, the algorithm can be followed as:

1. Proceed in the same direction until the last request in that direction.
2. If there is no request, stop and proceed towards other direction, if there is any request from other direction.

Links: <https://www.quora.com/What-is-the-best-answer-to-Design-an-elevator-system>

<https://www.quora.com/How-would-you-design-an-elevator>

Twitter Design:

*“Design a simplified version of Twitter where people can post tweets, follow other people and favorite\* tweets.”*

1) Ask Clarifying questions:

**How many users** do we expect this system to handle? Our interviewer says:

*“well… to make things interesting, let’s aim for 10 million users generating around 100 million requests per day”*

**Connections?** Since we have the notion of following someone, how connected will these users be? After all, they will form a graph with the users being the nodes and the edges will represent who follows whom.

*“we expect that each user will be following 200 other users on average, but expect some extraordinary users with tens of thousands of followers”*

**Tweets**: “Hm, that’s hard to say… we expect that there will be a maximum of 10 million tweets per day and each tweet will probably be favorited twice on average but again, expect some big outliers.”

Let’s make a few very simple calculations with the information we just received. We will have around 10 million users. Average number of followed other users is 200. This means that the network of users will have about 200 \* 10 million edges.

**Ask about availability and response time:** In addition to the expected size of different things, for a system like that it will be important to know what availability is expected and what response times are tolerable. Naturally, our interviewer wants to have a system, which loads pretty quickly. None of the operations described above should take more than a few hundred milliseconds. The system should be online all of the time

#### Requirements gathering: To summarize, here are some more things we now know:

* 10 million users
* 10 million tweets per day
* 20 million tweet favorites per day
* 100 million HTTP requests to the site
* 2 billion “follow” relations
* Some users and tweets could generate an extraordinary amount of traffic

**2) High level Design:**

we can divide our architecture in two logical parts: 1) the logic, which will handle all incoming requests to the application and 2) the data storage that we will use to store all the data that needs to be persisted.

a) logic: our application will need to handle requests for:

* posting new tweets
* following a user
* favoriting a tweet
* displaying data about users and tweets

The first three operations require things to be written somewhere in our database, while the last is more about reading data and returning it back to the user.

Therefore our architecture should allow the app to handle at least a few thousand requests per second at times.

In our particular problem we would definitely suggest using a load balancer, which handles initial traffic and sends requests to a set of servers running one or more instances of the application.

Behind the load balancer we will be running a set of servers that are running our application and are capable of handling the different requests that arrive.

b) Storing the data:

. First of all, users have profiles with some data fields attached to them. We’ll need to store that. Each user has a set of tweets that they have produced over time.

*“Sounds good, but could you tell me more about why reading from the cache would be better than just reading from the database?”*

 we could say that a database stores data on disk and it is much slower to read from disk than from memory. A solution like memcached stores data in memory, which provides way faster access.

Low level System design:

a) Database Schema

*“If you’re going to use a relational database for storing all the data could you draft the tables and the relations between them?”*

We have two main entities: users and tweets. There could be two tables for them.

#### Table users

* ID (id)
* username (username)
* full name (first\_name & last\_name)
* password related fields like hash and salt (password\_hash & password\_salt)
* date of creation and last update (created\_at & updated\_at)
* description (description)
* and maybe some other fields...

#### Table tweets

* ID (id)
* content (content)
* date of creation (created\_at)
* user ID of author (user\_id)

These two entities have several types of relations between them:

1. users create tweets
2. users can follow users
3. users favorite tweets

The first relation is addressed by sticking the user ID to each tweet. This is possible because each tweet is created by exactly one user. It’s a bit more complicated when it comes to following users and favoriting tweets. The relationship there is many-to-many.

For following user we can have a table like that:

#### Table connections

* ID of user that follows (follower\_id)
* ID of user that is followed (followee\_id)
* date of creation (created\_at)

Let’s also add a table, which represents favorites. It could have the following fields:

#### Table favorites

* ID of user that favorited (user\_id)
* ID of favorited tweet (tweet\_id)
* date of creation (created\_at)

### **Building a RESTful API**

The API endpoints will likely be built around the data entities that we have and the needs of the user-facing part of the application.

**GET /api/users/<username>**

**GET /api/users/<username>/tweets**

**GET /api/users/<username>/tweets?page=4**

**GET /api/users/<username>/followers**

**GET /api/users/<username>/followees**

**POST /api/users/<username>/tweets**

**GET /api/users/<username>/tweets/<tweet\_id>/favorites**

<https://www.hiredintech.com/classrooms/system-design/lesson/67>

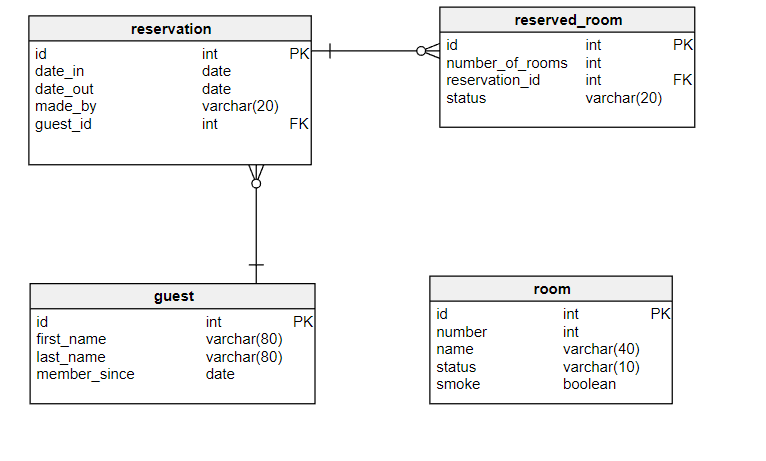
<https://www.quora.com/What-are-some-of-the-best-answers-to-the-question-How-would-you-design-Twitter-in-a-system-design-interview>

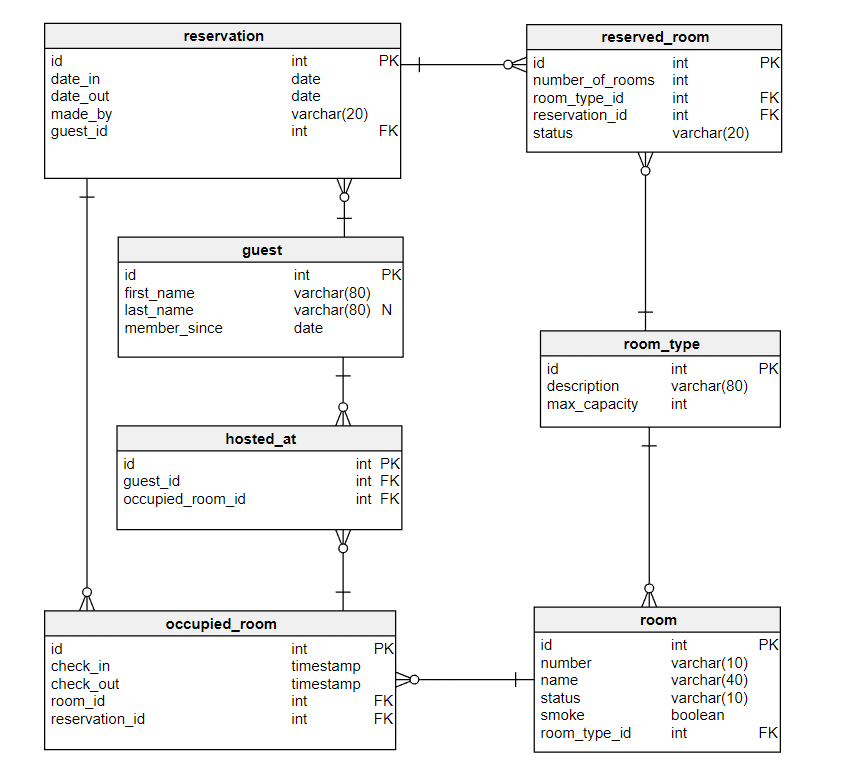
Hotel Reservation System design:

When designing a hotel reservation process, it is helpful to break it up into 3 basic components:

1. Search.
2. Results.
3. Booking Validation.

Ask questions – type of hotel, rooms, location, floors, guests, facilities, booking type,…





Main Classes:

1.User  
2.Room  
3.Hotel  
4.Booking  
5.Address  
6.Facilities

|  |
| --- |
| // Java code skeleton to design an online hotel  // booking system.  Enums:    public enum RoomStatus {      EMPTY          NOT\_EMPTY;  }    public enum RoomType {      SINGLE,      DOUBLE,      TRIPLE;  }    public enum PaymentStatus {      PAID,      UNPAID;  }    public enum Facility {      LIFT;      POWER\_BACKUP;      HOT\_WATERR;      BREAKFAST\_FREE;      SWIMMING\_POOL;  }    class User {        int userId;      String name;      Date dateOfBirth;      String mobNo;      String emailId;      String sex;  }    // For the room in any hotel  class Room {        int roomId; // roomNo      int hotelId;      RoomType roomType;      RoomStatus roomStatus;  }    class Hotel {        int hotelId;      String hotelName;      Adress adress;        // hotel contains the list of rooms      List<Room> rooms;      float rating;      Facilities facilities;  }    // a new booking is created for each booking  // done by any user  class Booking {      int bookingId;      int userId;      int hotelId;        // We are assuming that in a single      // booking we can book only the rooms      // of a single hotel      List<Rooms> bookedRooms;        int amount;      PaymentStatus status\_of\_payment;      Date bookingTime;      Duration duration;  }    class Address {        String city;      String pinCode;      String state;      String streetNo;      String landmark;  }    class Duration {        Date from;      Date to;    }    class Facilities {        List<Facility> facilitiesList;  } |

<http://cs.umd.edu/~samir/498/Amazon-Recommendations.pdf>

Parking Lot system design:

Ask if this is System design question or a OOD design question?

Ask Clarifying questions:

1)How is the parking lot design? – building, open lot,..

2) how many spots—10.,…1000..parking in multiple buildings??

3)Does it have multiple floors? Is there a prob of getting cars from one level to another level

4) Dependencies btw levels? Should we fill top floors first and the lower ones

5) pricing based on spots, or on car size..? premium spots, spots for premium members, handicapped

Design a system with 4 sizes of parking spots – small, med, larg, xl

Assume smaller cars can be put in bigger spots…eg cars in bus spot …etc

Other way round is not possible

Class hierarchy:

Think about the entities:

Abstract vehicle class

* + String licensePlate
  + Int noOfWheels
  + enum color
  + Int yearOfMfg

Car, MotorCycle, Bus, Truck …extends Vehicle

Class ParkingLot

* + Spot placeVehicle(Vehicle veh){..}

Class Spot

* + Long id
  + Int floorLevel
  + Enum size

Coding a functionality…placing and retrieving car at a fast rate..

* 4 stacks for placing open spots for s,m,l,xl
* Therefore, placeVehicle will take O(1)…coz of stack

Spot RemoveVehicle(Vehicle veh)…

* Use hashmap for storing the vehicle/spot pair

// Vehicle and its inherited classes.

public enum VehicleSize { Motorcycle, Compact,Large }

public abstract class Vehicle

{

      protected ArrayList<ParkingSpot> parkingSpots =

                           new ArrayList<ParkingSpot>();

      protected String licensePlate;

      protected int spotsNeeded;

      protected VehicleSize size;

      public int getSpotsNeeded()

      {

          return spotsNeeded;

      }

      public VehicleSize getSize()

      {

          return size;

      }

      /\* Park vehicle in this spot (among others,

         potentially) \*/

      public void parkinSpot(ParkingSpot s)

      {

          parkingSpots.add(s);

      }

      /\* Remove vehicle from spot, and notify spot

         that it's gone \*/

      public void clearSpots() { ... }

      /\* Checks if the spot is big enough for the

         vehicle (and is available).

         This \* compares the SIZE only.It does not

        check if it has enough spots. \*/

      public abstract boolean canFitinSpot(ParkingSpot spot);

}

public class Bus extends Vehicle

{

    public Bus()

    {

        spotsNeeded = 5;

        size = VehicleSize.Large;

    }

    /\* Checks if the spot is a Large. Doesn't check

     num of spots \*/

    public boolean canFitinSpot(ParkingSpot spot)

    {... }

}

The **ParkingSpot** is implemented by having just a variable which represents the size of the spot. We could have implemented this by having classes for LargeSpot, CompactSpot, and MotorcycleSpot which inherit from ParkingSpot, but this is probably overkilled. The spots probably do not have different behaviors, other than their sizes.

|  |
| --- |
| public class ParkingSpot  {      private Vehicle vehicle;      private VehicleSize spotSize;      private int row;      private int spotNumber;      private Level level;        public ParkingSpot(Level lvl, int r, int n,                           VehicleSize s)      { ... }        public boolean isAvailable()      {          return vehicle == null;      }        /\* Check if the spot is big enough and is available \*/      public boolean canFitVehicle(Vehicle vehicle) { ... }        /\* Park vehicle in this spot. \*/      public boolean park(Vehicle v) {..}        public int getRow()      {          return row;      }      public int getSpotNumber()      {          return spotNumber;      }        /\* Remove vehicle from spot, and notify        level that a new spot is available \*/      public void removeVehicle() { ... }  } |

<https://codereview.stackexchange.com/questions/170922/parking-lot-oo-design>

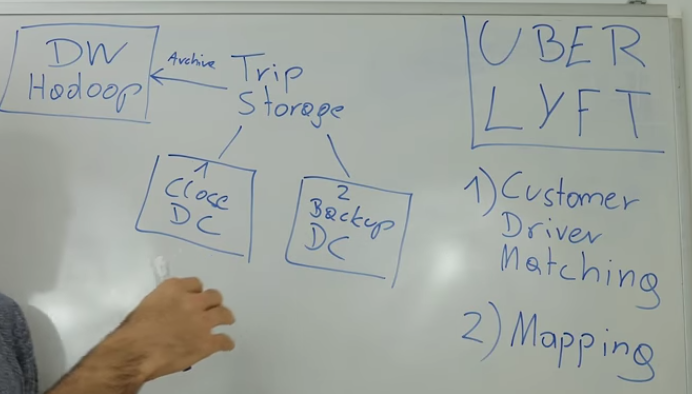
<http://blog.gainlo.co/index.php/category/system-design-interview-questions/?utm_campaign=quora&utm_medium=How+do+I+answer+design-related+questions%2C+like+design+a+parking+lot%2C+in+an+Amazon+interview%3F&utm_source=quora>

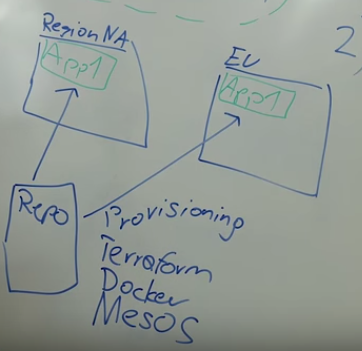
<https://discuss.leetcode.com/topic/94763/parking-lot-design-using-oo-design/3>

Design Uber/ Lyft

While designing a ride-sharing service, discuss things like:

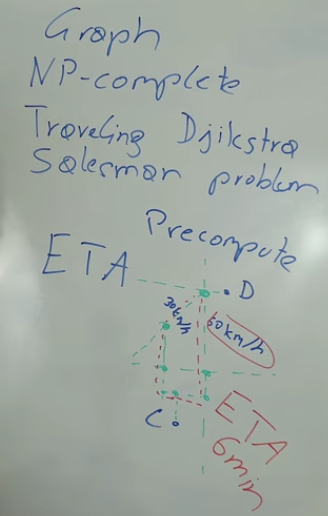
* The most critical use case — when a customer requests a ride and how to efficiently match them with the nearby drivers?
* How to store millions of geographical locations for drivers and riders who are always moving.
* How to handle updates to driver/rider locations (millions of updates every second)?





Mapping – Graphs problem

* + Getting from one node to another – shortest path ( dijkstra’s …)
  + Travelling salesman prob
  + ETA calculation



**Architecture Overview**  
What drives it all are riders and drivers on their mobile phones running native applications.  
  
The backend is primarily servicing mobile phone traffic. Clients talk to the backend over mobile data and the best effort Internet.  
  
Clients connect to the dispatch system which matches drivers and riders, the supply and demand.  
Dispatch is written almost entirely in node.js.

**Maps/ETA (estimated time of arrival)** - Street maps and historical travel times are used to estimate current travel times.

**Databases. A lot of different databases are used.**  
The oldest systems were written in Postgres.  
Redis is used a lot. Some are behind Twemproxy. Some are behind a custom clustering system.  
MySQL  
Uber is building their own distributed column store that’s orchestrating a bunch of **MySQL** instances.  
Some of the Dispatch services are keeping state in Riak.

**Post trip pipeline. A lot of processing must happen after a trip has completed.**  
Collect ratings.  
Send emails.  
Update databases.  
Schedule payments.

**Dispatch**

* Geo by supply makes a coarse first pass filter to get nearby candidate that meet requirements.
* Then the list and requirements are sent to routing / ETA to compute the ETA of how nearby they are not geographically, but by the road system.
* Sort by ETA then send it back to supply to offer it to a driver.