**Following is the Agent’s functionality with its output:**

* Install OpenAI by running following command to get support of **GPT-4** model.

!pip install openai==0.28

**CentralizedControlAgent:**

* The **CentralizedControlAgent** has methods for planning routes and allocating resources.
* The plan\_routes method plans routes for each vehicle based on user requests and preferences using the Large Language Model.

**centralizedControl\_agent.plan\_route\_for\_vehicle(vehicle1, "Oxford", "Reading", "shortest path")**

* Following is the output when user enters current\_location is **Oxford** and destination is **Reading** and user like to drive on shortest path to reach early.

Vehicle 1: Route planned - 1. Start on High St/ from Oxford city center.

2. Turn onto Magdalen Bridge/A420.

3. Continue to follow A420.

4. At the roundabout, take the 1st exit onto Northern Bypass Rd/A40.

5. At the roundabout, take the 3rd exit onto the A34 slip road to M40/M4/Newbury/Reading/Wycombe/London.

6. Merge with A34.

7. At the junction for the A4130, take the A4130 exit to Wallingford/Didcot/Henley.

8. At the roundabout, take the 2nd exit and stay on A4130.

9. Keep left at the fork, follow signs for Reading/M4/Wallingford/B4009.

10. At the roundabout, take the 3rd exit onto Wallingford Rd/A4074

11. Continue to follow A4074.

12. At the roundabout, take the 2nd exit and stay on A4074.

13. Use the right 2 lanes to turn slightly right onto Caversham Rd/A4155

14. Turn right onto Richfield Ave

15. Continue straight to stay on Richfield Ave.

16. Finally, arrive at Reading.

This is the shortest path from Oxford to Reading according to the preferences.

* The **allocate\_resources** method allocates resources to vehicles based on their planned routes.
* Following is the output in which large language model gives advice for resource allocation.

Vehicle 1: Resources allocated - The resources that need to be allocated for Vehicle 1 on this route include:

1. Fuel: The total distance between Oxford and Reading is approximately 44 miles. If the vehicle gets 30 miles per gallon, approximately 1.5 gallons of fuel will be needed.

2. Time: The estimated travel time is around 1 hour and 15 minutes under the normal traffic condition. This is an important resource to consider as well for scheduling and logistics planning.

3. Driver: A driver is needed for the route. It is essential to figure out whether a dedicated driver will do this route or if it fits into another driver's schedule effectively.

4. Vehicle Maintenance: Given this vehicle will be driving at least 88 miles for a round trip, regular vehicle maintenance should be involved in allocation; careful check before departures such as oil, tire pressure, and engine performance to ensure safety.

5. Funds: Financial resources are also crucial. These are associated with fuel cost, maintenance cost, driver's pay, and any unexpected expenses that might arise on the route.

6. Emergency Services: Ensure that roadside assistance is available during the entire route in case of any breakdowns or emergencies.

7. Technological Resources: Navigation system updated with the route for efficient and accurate directions; communication device for the driver to stay in contact with the central office.

8. Backup Plans: In case of roadblocks or heavy traffic on A34 or A4074, it will be wise to have resources allocated for an alternate route. For instance, the M4 can be an alternative for A34 and A4130.

Remember, proper resource allocation is essential for efficiency, cost-effectiveness, and safety in this journey.

**LocalNavigationAgent:**

* The LocalNavigationAgent is responsible for local navigation using lidar data for obstacle avoidance.

**# Set initial vehicle location and destination**

**Vehicle1.update\_location("Oxford")**

**Vehicle1.update\_destination("London Bridge")**

**localNavigation\_agent.navigate()**

* The **navigate** function checks for obstacles using simulated lidar data. If an obstacle is detected, it generates an alternative route with the help of the Large Language Model.
* Following is the output which is generated by large language model where the current\_location is **Oxford** and destination is **London Bridge**, it shows obstacles arrives and advice for alternative route.

Vehicle 1: Obstacle detected! Generating alternative route - Vehicle 1 will start the journey from Oxford and take the A420 towards Swindon. Continue on A420 towards Wantage. Take the B4507 and A417 to A34 in East Ilsley. Follow A34 and M4 to W London. Use the right 2 lanes to take the A4 exit towards Central London/Hammersmith. Continue on A4 to reach A315. Turn right onto Knightsbridge/A315/A4 and continue following A4. Turn right onto Piccadilly Circus/A4 and continue following A4. Use any lane to turn slightly left onto New Oxford St. Continue on A201. Drive to King William St/A3 in London. Keep left to continue towards King William St/A3. Use the middle 2 lanes to continue on King William St/A3. Continue straight onto London Bridge/A3 to reach your destination.

**CommunicationAgent:**

* communicationAgent is responsible for sharing information about traffic conditions between different vehicles within the system.

Vehicle 1: Sharing traffic info with Vehicle 1 - Vehicle 1 is currently located on Weber Street, moving at an average speed of 35 mph. Moving in a north-east direction, the vehicle is expected to experience light traffic ahead. There are minor delays expected around the junction of Weber Street and Schmidt Boulevard due to ongoing roadwork, however, alternative routes via Hansen Street are available. Following the main route, the estimated travel time to the final destination is approximately 45 minutes. No major accidents or roadblocks have been reported in the vicinity. Please adhere to all posted speed limits and drive safely.

Vehicle 2: Sharing traffic info with Vehicle 2 - Current Location: 5th Avenue, Downtown

Destination: Central Park

Traffic Information:

- Light traffic on 5th Avenue towards Madison Avenue

- Moderate traffic congestion reported on Madison Avenue due to construction works, consider taking Lexington Avenue

- Heavy traffic at Lexington Avenue and 57th Street intersection due to ongoing parade, expected delay 15 minutes

- Rest of the route towards Central park is clear.

Estimated travel time: 25 minutes (including delays).

**EnergyManagementAgent:**

* The **optimize\_charging\_schedule** method optimizes the charging schedule based on the estimated energy needs, available charging stations, and the characteristics of the best charging station.
* The **estimate\_energy\_needs** method estimates the energy needs of the vehicle based on the planned route and user preferences using the Large Language Model.
* The **find\_available\_charging\_stations** method identifies charging stations within the vehicle's range that are currently available.
* The **find\_best\_charging\_station** method determines the nearest best charging station.
* The **generate\_charging\_schedule** method generates a charging schedule using the Large Language Model based on energy needs and charging station characteristics.

Vehicle 1: Optimized charging schedule - Based on the route distance and vehicle type, it's also important to consider how long the vehicle will be at Charging Station 1 in order to determine how much of its energy needs can be fulfilled there. For instance, if the charging station can deliver energy at a rate of 50 kW and the vehicle will be there for two hours, the vehicle can receive up to 100 kWh of energy, given no losses in efficiencies while charging.

Assuming the station is delivering electricity, if Vehicle 1 is a gasoline vehicle, then its refueling needs have to be calculated differently as it will have to stop at a gas station. Consider the working hours of the charging station as well. Some stations may not operate 24/7 and this will require scheduling a suitable time to charge the vehicle.

Additionally, if the vehicle supports fast charging, more energy can be delivered in the same amount of time. Note that not all vehicles are compatible with all types of chargers.

Here's the schedule assuming none of these factors will limit the charging time:

For electric Vehicle 1:

1. Begin charging upon arriving at Charging Station 1.

2. Allow the vehicle to charge for the full two hours (or as long as possible within the station's working hours).

3. End charging and continue driving.

For gasoline Vehicle 1:

1. Plan a stop at a gas station instead of Charging Station 1.

2. Refuel your vehicle (this usually takes less than 10-15 minutes).

3. Continue driving.

**SafetyMonitoringAgent:**

* The **monitor\_safety** method retrieves LiDAR data, performs safety analysis, and takes appropriate safety actions.
* The **perform\_safety\_analysis** method uses the Large Language Model to analyze safety based on LiDAR data.

Vehicle 1: Safety analysis - Analyzing LiDAR (Light Detection and Ranging) data can give us insights into the safety and potential obstacles or hazards around a vehicle. Here we have three points of data, each of them potentially represent distance measurements from the vehicle to an object in meters.

1. Data Point 1: 200 meters - This distance shows that an object is relatively close to the vehicle. While it's not immediately a safety concern depending on the speed and direction of travel, it should place the vehicle on some levels of alert for the possibility of requiring fture actions such as slowing down or changing direction.

2. Data Point 2: 300 meters - This distance gives the vehicle ample space and time to continue moving safely or to react, if necessary. The situation can be considered safe based on this data point alone.

3. Data Point 3: 500 meters - At this distance, the object is pretty far off from the vehicle. It is currently not a safety concern in any normal driving circumstances.

Summary: According to the provided LiDAR data, Vehicle 1 is in a safe condition at the moment but it is potentially within range of encountering an object (or objects) in the near future, considering its speed, course, and other road conditions. Thus, it should stay alert and continue analyzing incoming data to ensure its ongoing safety.

**MaintenanceAgent :**

* The **monitor\_vehicle\_health** method generates a health report using the Large Language Model and, if critical issues are detected, it schedules maintenance.

Vehicle 1: Health report - Vehicle Health Report - Vehicle 1

1. Engine Performance: Excellent

The vehicle's engine performance is optimal with no significant issues detected during the inspection. Regular maintenance services are carried out to ensure this.

2. Battery Health: Good

The battery is in good health, with charging levels at normal range.

3. Brake System: Excellent

Brake pads are in excellent condition. The brake system has been checked and there was no sign of damage or wear.

4. Tyre Condition: Fair

Vehicle's front tires are wearing faster than the rear ones indicating alignment issue. We recommend a tyre rotation and wheel alignment.

5. Transmission: Good

Transmission fluid levels are normal and there are no perceived issues with the vehicle's transmission system.

6. Cooling System: Excellent

The cooling system is functioning optimally ensuring the engine maintains a healthy temperature while the vehicle is in operation.

7. Suspension and Steering: Good

No major issues detected with suspension and steering. Slight wear is shown but is normal due to the vehicle's age.

8. Body Condition: Good

The vehicle's bodywork is in good condition with only minor scratches and dents.

9. Lighting Systems: Excellent

All the lights have been tested and are functioning as expected.

10. Exhaust system: Excellent

There are no leaks or damages in the exhaust system. Corrosion is within acceptable levels.

11. Interior condition: Excellent

The interiors of the car, including upholstery, carpets, and facilities like AC, are in excellent condition.

* The **generate\_health\_report** and **generate\_maintenance\_plan** methods use the Large Language Model to generate health reports and maintenance plans, respectively.

Vehicle 1: Scheduling maintenance - Vehicle Maintenance Plan: Vehicle 1

1. Weekly Maintenance:

- Check Tire Pressure: Ensuring that the vehicle's tires are properly inflated can save on fuel and prevent potential hazards.

- Clean the Exterior: Maintain the vehicle's aesthetic by a weekly exterior clean. Besides enhancing its appearance, it helps to prevent scratches and dents.

2. Monthly Maintenance:

- Check Fluid Levels: Checking and replenishing engine oil, brake fluid, power steering fluid, transmission fluid, and coolant should be done monthly.

- Check Lights: Check all lights and replace any that are not functioning properly.

- Inspect Belts & Hoses: Checking for any signs of wear and tear and replacing them if necessary should happen on monthly basis.

3. Quarterly Maintenance:

- Replace Windshield Wipers: Wipers should be replaced approximately every three months to ensure clear visibility during adverse weather conditions.

- Check Brakes: This includes checking the brake pads and rotors for wear, and brake fluid for clarity.

- Battery Check: Ensure the battery is functioning well and that its terminals are clean.

4. Biannual Maintenance:

- Air Filter Replacement: It should be replaced every six months to ensure fuel efficiency and prolong engine life.

- Brake Fluid Change: Replace brake fluid every two years to prevent damage to the braking system.

- Engine Coolant Check: This helps prevent overheating and should ideally be replaced every two years.

5. Yearly Maintenance:

- Professional Inspection: Have a trusted mechanic inspect the vehicle thoroughly for any potential issues.

- Transmission Fluid Change: Changing the transmission fluid and filter once a year provides a comfortable drive.

- Spark Plug Replacement: Yearly replacement ensures optimal fuel economy and vehicle performance.

Remember to check your vehicle's user manual to confirm manufacturer's recommendations. Always record each maintenance task to keep track of what has been done and what needs to be

**UserAgent :**

* The **request\_ride** method initiates a ride request to a specified destination.

**user\_agent.request\_ride("Oxford", "London")**

User 1: Received route plan - Route Plan:

1. Start from Oxford City Centre.

2. Take the route to join A40 towards London, heading southeast.

3. Continue on A40 for about 5 miles.

4. At the roundabout, take the 3rd exit onto the M40 ramp to London

5. Merge onto M40. Continue on M40 for about 52 miles.

6. Take the A40 exit towards Denham.

7. Continue on Western Ave/A40. Keep right at the fork, follow signs for A3220/N Circular/A406/Wembley/West End Paddington.

8. Continue onto Western Avenue A40.

9. Enter the roundabout and take the 2nd exit onto Westway/A40.

10. Continue on Marylebone Flyover/A501. Take A5 to Craven Rd/B410 in London.

11. At Marble Arch, Use the 2nd from the left lane to turn right onto Bayswater Rd

* The **ask\_question** method simulates a user asking a question.

**user\_agent.ask\_question("How can I optimize my route?")**

Received AI Assistant Reply - User 2: You can use a route optimization software or app that is equipped with GPS features. These tools will consider factors like distance, travel time, traffic, and road conditions to give you the most efficient route. You can also manually optimize it by planning ahead, taking into consideration rush hours, and known road works or closures. Always having a backup plan will also help just in case your initial route is not viable.