Object-Oriented Programming: Autonomous Vehicle Simulation

Winter Semester - Academic Year 2025-2026

1. Project Overview

This project involves a simplified simulation of a fully autonomous self-driving car (full self-driving) navigating a **GridWorld** using GPS targets. The system is designed to demonstrate core Object-Oriented Programming (OOP) principles: **Encapsulation**, **Inheritance**, **Polymorphism**, **Composition**, and **Messaging**.

2. System Architecture

2.1 The GridWorld

- **Environment:** A 2D grid of specific dimensions (default: 40x40 cells).
- **Entities:** Populated with various `WorldObject` instances placed in random positions.
- **Simulation Loop:** The simulation runs in discrete time units called **ticks**.

2.2 Simulation Logic (Per Tick)

1. **Update Phase:** All world objects update their internal state (e.g., moving vehicles update position, traffic lights update color).
2. **Perception Phase:** The autonomous vehicle collects data from its sensors.
3. **Fusion & Decision Phase:** The **Sensor Fusion Engine** merges data, and the **Navigation System** decides the next move based on current GPS goals.
4. **Action Phase:** The vehicle updates its speed and executes its movement.

3. Object Specifications

Every object has a unique alphanumeric **ID** (e.g., `BIKE:4`) and a **glyph** character for visualization.

3.1 Static Objects (`StaticObjects`)

- **Stationary Vehicles:** Parked cars that remain in a fixed position.
- **Traffic Signs:** Includes informational signs, but only the **STOP** sign affects the vehicle's driving behavior in this simulation.
- **Traffic Lights:** Cycle through **RED** (4 ticks) → **GREEN** (8 ticks) → **YELLOW** (2 ticks) → **RED**.

3.2 Moving Objects (`MovingObjects`)

- **Behavior:** Move at a constant speed in a fixed direction chosen randomly at creation.
- **Removal:** If a moving object attempts to travel outside the grid boundaries, it is removed from the simulation.

4. The Autonomous Vehicle

4.1 Movement and Speed

The car manages three speed states:

- **STOPPED**
- **HALF_SPEED**
- **FULL_SPEED** (2 cells per tick)

Deceleration triggers: The vehicle must slow down or stop if it detects a RED/YELLOW light within 3 cells, a GPS target within 5 cells, or an obstacle (moving object) within 2 cells.

4.2 Navigation

The car follows a list of GPS coordinates provided at launch. Distance between cells is calculated using the **Manhattan Distance** formula:

$$Dist = |x_2 - x_1| + |y_2 - y_1|$$

5. Sensors and Perception

5.1 Sensor Types

Sensor	Range	FOV	Detection Capabilities
Lidar	9 cells	9x9 (360°)	All objects; No color/text
Radar	12 cells	Straight line	Moving objects only
Camera	7 cells	7x7 (front)	All objects + Color/Text

5.2 Accuracy and Confidence

Each sensor reading includes a **confidence score** (0.0 to 1.0):

- **Base Precision:** Excellent (99%), High (95%), Medium (87%), or Low (75%).
- **Distance:** Confidence decreases linearly as the object approaches the sensor's range limit.
- **Noise:** A random noise factor of ± 0.05 is added to every reading.

5.3 Sensor Fusion Engine

The engine standardizes all data into a `SensorReading` format. It uses a **weighted average** (where higher confidence readings carry more weight) to merge data for objects detected by multiple sensors.

- **Threshold:** Readings below a `minConfidenceThreshold` are discarded.
- **Safety Exception:** If any sensor detects a **Bicycle**, the reading is never discarded.

6. Execution Parameters

The program must handle command-line arguments in pairs:

- `--seed <n>`: Random generator seed (default: current time).
- `--dimX <n>`, `--dimY <n>`: Grid dimensions (default: 40x40).
- `--simulationTicks <n>`: Maximum duration of the simulation.
- `--minConfidenceThreshold <n>`: Cutoff for sensor data (default: 0.40).
- `--gps <x1> <y1> <x2> <y2>...`: **(Required)** List of GPS target coordinates.

7. Visualization Symbols

Symbol	Object	Priority
@	Self-Driving Car	1
R/G/Y	Traffic Light	2
S	Stop Sign	3
B	Moving Bike	4
C	Moving Car	5
P	Parked Car	6
.	Empty Cell	-
X	Out of Bounds	-