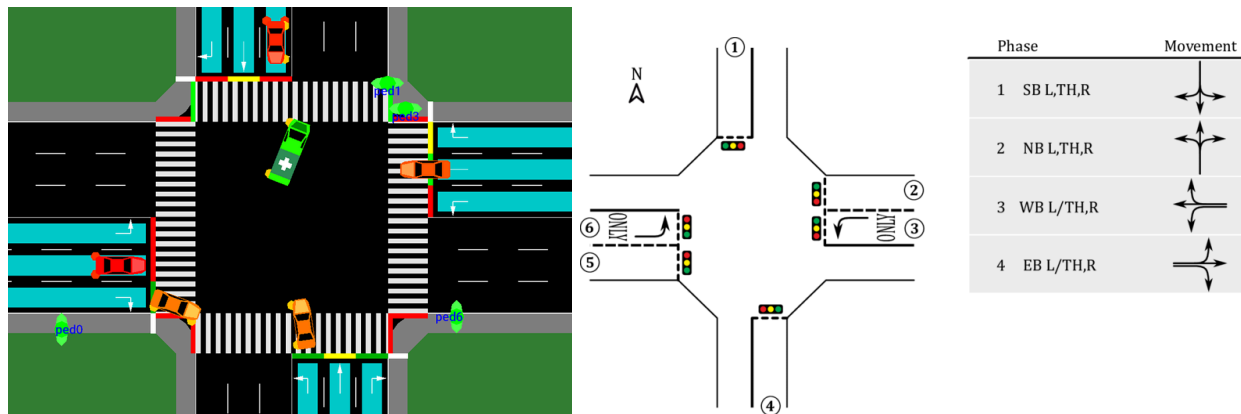


The goal is to manage traffic flow efficiently by dynamically adjusting traffic signal phases to minimize congestion, delays, and conflicts.



Safety

- **Requirement:** When an action is chosen too frequently by RL agent, the TSC shall discourage agent
- **Potential Design Solutions:**
 - Given that the only means to extend traffic time is by repetition of a particular action
 - Implement maximum times an action could be repeated
 - Incorporate penalty that discourages excessive repetition of action in the reward function
- **Requirement:** If embedded system encounters floating point leakage, then the TSC shall enter self diagnostic mode or safe mode
- **Potential Design Solutions:**
 - Implement self diagnostic mode that detects and corrects potential causes such as timing, precision
 - Implement baseline for safe mode either architected by human or prevalidated validate agent
- **Requirement:** When state space values are too noisy, the TSC shall utilize checks for statistical realism
- **Potential Design Solutions:**
 - Develop realistic simulations of real-world situations to build statistical model
 - Implement ensemble of model for extraction of road features that determines the state space values
- **Requirement:** The traffic signal control system shall prevent conflicts between vehicles in different directions at the intersection.
- **Potential Design Solutions:**
 - Implement conflict detection algorithms that take into account vehicle speed, direction, and lane occupancy.

- Develop a safety mechanism that temporarily overrides the optimal policy if it would result in an unsafe situation (e.g., by prioritizing pedestrian movement over vehicle traffic).
- **Requirement:** The traffic signal control system shall ensure that vehicles have sufficient time to clear intersections safely.
- **Potential Design Solutions:**
 - Calculate optimal green light duration based on estimated queue lengths and expected traffic volume.
 - Implement dynamic timing adjustments to account for changing conditions (e.g., accidents, inclement weather).
- **Requirement:** When a vehicle with high speed suddenly approach intersection, the traffic control system shall
- **Potential Design Solutions:**
 - Utilize multiple long horizon sensors that monitor overspeeding cars from far distance
- **Requirement:** When special events happens, the TSC shall handle with priority
- **Potential Design Solution:**
 - Implement priority allocation for pedestrian and cyclist movements during peak hours.
 - Implement dynamic priority allocation for emergency vehicles or special events (e.g., road closures).

Privacy & Security

- **Requirement:** The traffic signal control system shall protect user personal data (e.g., license plate numbers, vehicle ownership information).
- **Potential Design Solutions:**
 - Implement robust encryption methods to secure data transmission between devices.
 - Use anonymized data to improve accuracy of predictions and prevent targeted advertising.
- **Requirement:** The TSC system shall make transparent decision at all time
- **Potential Design Solutions:**
 - Investigate RL agent decision making with explainable RL techniques
 - Implement a replica systems that decipher the blackbox decision of the agent

Maintainability

- **Requirement:** The traffic signal control system shall provide detailed logs and analytics for monitoring performance and debugging issues.
- **Potential Design Solutions:**
 - Implement a log aggregation system that collects data from all sensors and devices.

- Develop an analytics platform that provides insights into system performance, including queue lengths, vehicle speeds, and conflict rates.
- **Requirement:** The TSC system shall be designed to minimize downtime and optimize maintenance schedules to ensure continuous operation.
- **Potential Design Solutions:**
 - Utilize predictive analytics to forecast maintenance needs and schedule routine checks accordingly.
 - Establish regular testing and inspection procedures to ensure system functionality.

General recommendations:

- The state space focuses more on the vehicle related states, while the pedestrian and cyclist are also important.
- Although most roads are already equipped with CCTV cameras, for privacy, other sensors like LiDAR could be considered.
- For the agent to run on low computational device locally, tinyML implementations should be considered e.g <https://rl.tools/>
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