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Machine learning for road active safety global dynamic drone assisted lane change maneuver for risk prevention and collision avoidance

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Publications

1. J. Hao, R. Naja, D. Zeghlache, "GL-DEAR: Global Dynamic Drone Assisted Lane Change Maneuver for Risk Prevention and Collision Avoidance," accepted by ICC 2023

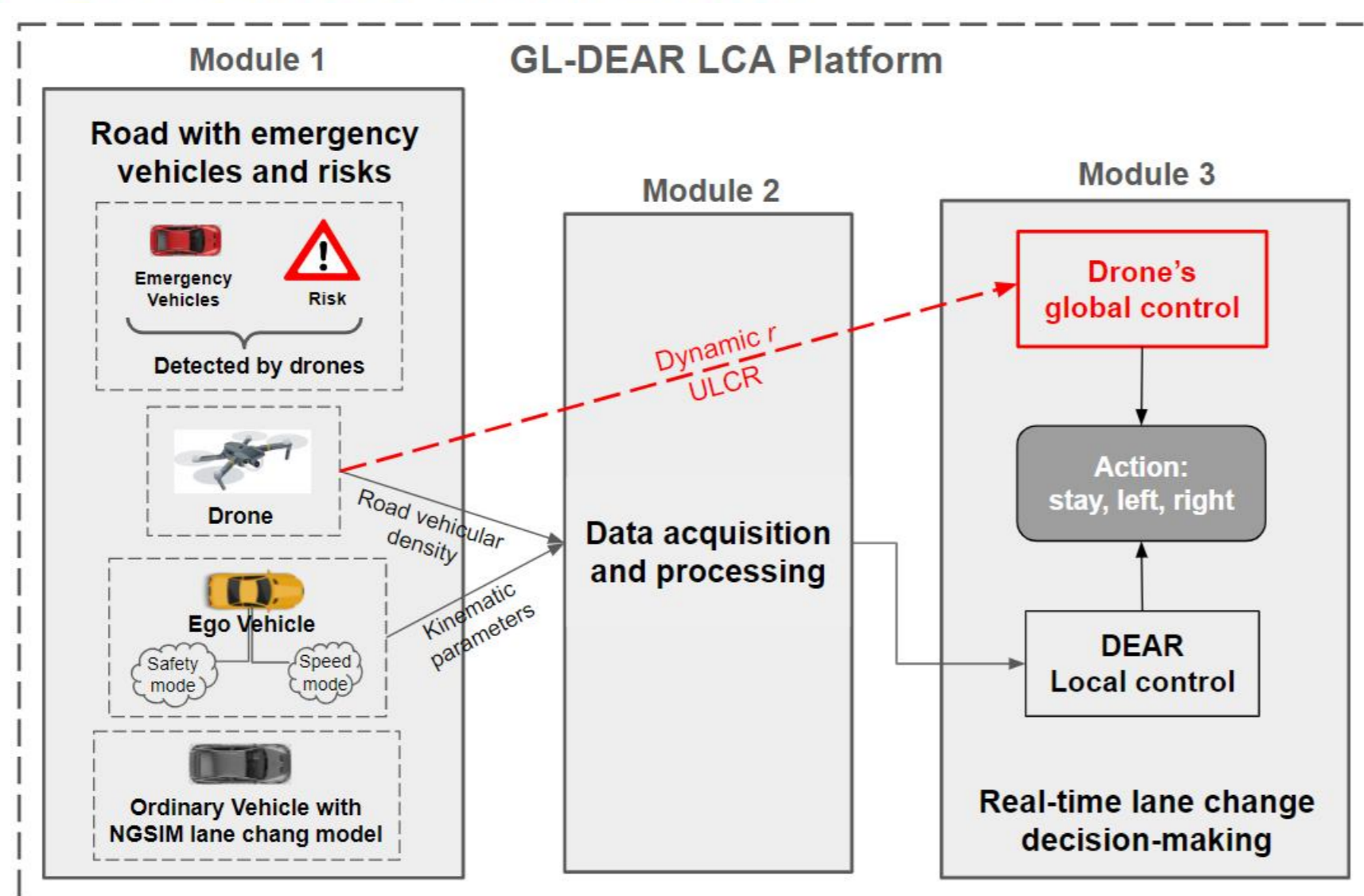
2. J. Hao, R. Naja, D. Zeghlache, "Drone-Assisted Lane Change Maneuver using Reinforcement Learning with Dynamic Reward Function," IEEE WiMob 2022, October, Greece

I. MOTIVATION

LANE CHANGE FOR DRONE-ASSISTED VEHICULAR NETWORKS

- Lane change (LC) leads to frequent car accidents
- There is an urgent need to timely LC decision-making
- We implemented a GL-DEAR platform
 - based on deep reinforcement learning method
 - assisted by drones to capture global view of the traffic
 - dealing with road potential risks and emergency vehicles

II. GL-DEAR PLATFORM

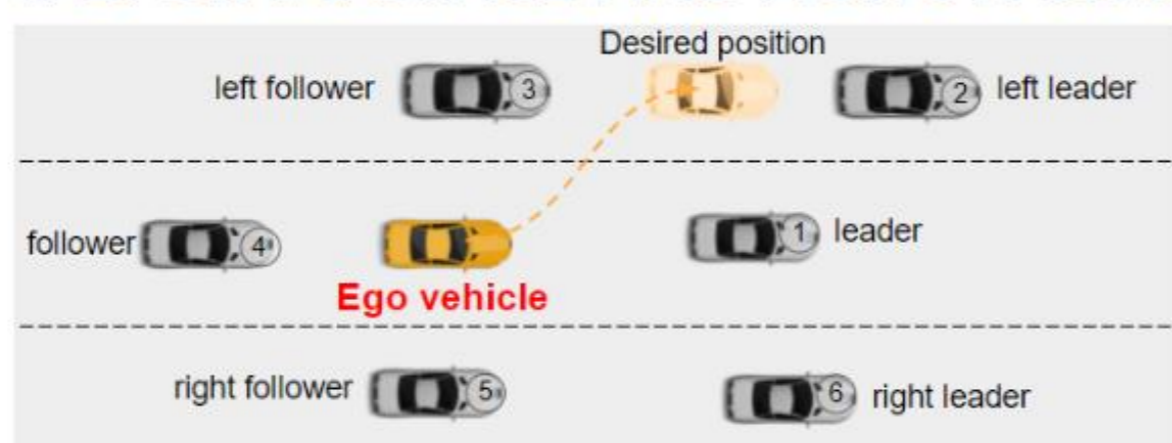


II-1. DEEP Q-NETWORK BASED ON A DYNAMIC REWARD FUNCTION

$$R = w_{comf}R_{comf} + w_{eff}R_{eff} + w_{safe}R_{safe}$$

- R_{comf} reduces sharp brakes and sudden accelerations
- R_{eff} increases speed and reduces unnecessary lane changes
- R_{safe} increases road active safety:
 - $R_{safe} = R_{den} + R_{colli} + R_{risk} + R_{block}$
 - R_{den} is related to road vehicular density, which is calculated by drones
 - R_{colli} is related to collision number, and is **dynamically adjusted by drones**
 - R_{risk} and R_{block} consider road potential risks and emergency vehicles

II-2. STATE SPACE AND ACTION SPACE



- State space: $o[j] = \{o_{ego}[j], o_1[j], \dots, o_6[j]\}$, where:
 - $o_{ego}[j] = \{l_{risk}[j], x_{ego}[j], y_{ego}[j], v_{ego}[j], a_{ego}[j], l_{ego}[j]\}$ contains road risk label, kinematic parameters and current lane id of the ego vehicle at step j
 - $o_i[j] = \{x_i[j], y_i[j], v_i[j], a_i[j], l_i[j], d_i[j], p_i[j]; i \in [0, 6]\}$ consists of the kinematic parameters, current lane id, distance to ego vehicle and vehicle priority of ego's i -th neighbor at step j

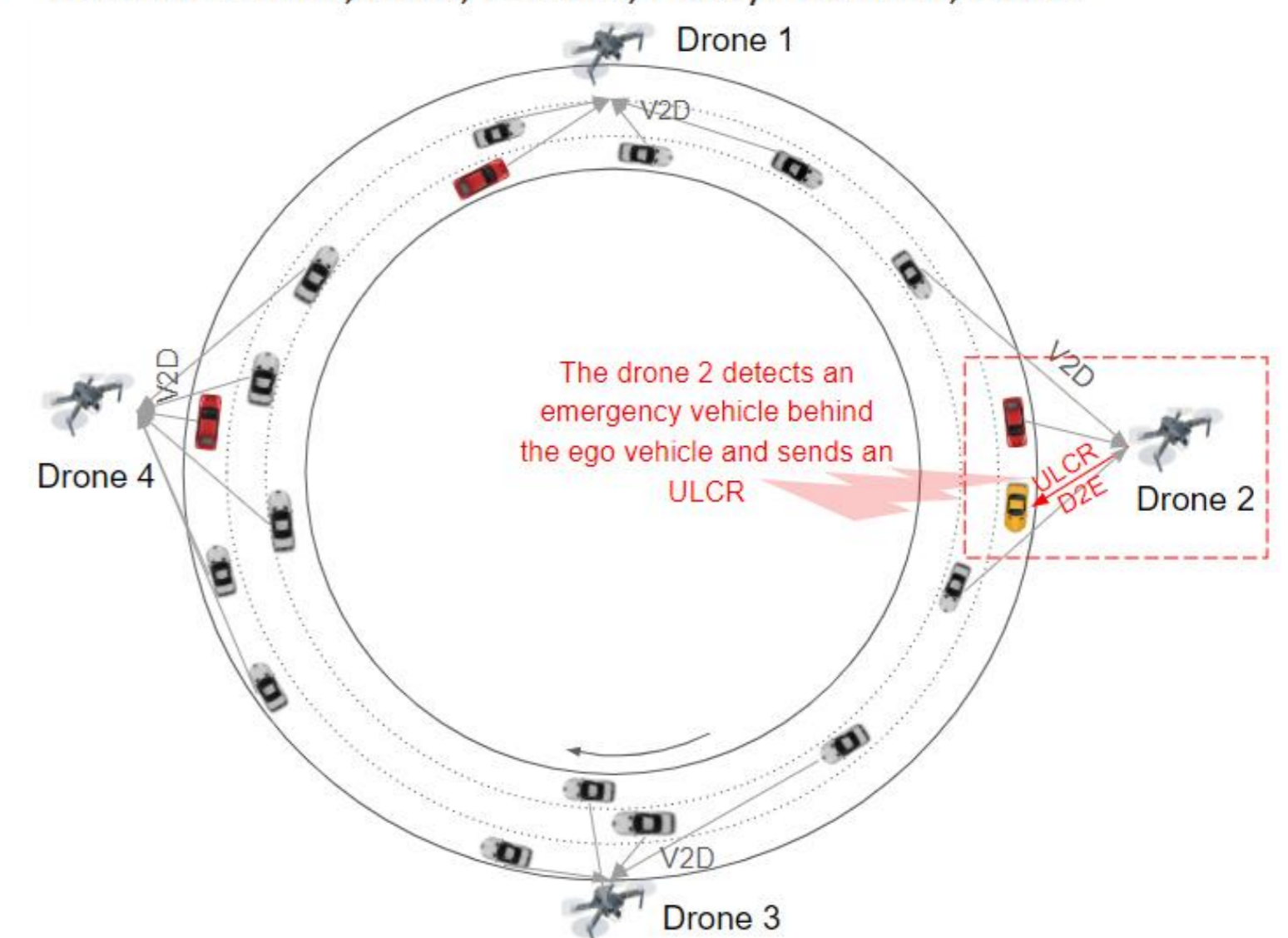
II-3. DRONES PLAY AN IMPORTANT ROLE IN RISK PREVENTION AND COLLISION AVOIDANCE

- The drones
 - calculate the road vehicular density
 - dynamically adjust R_{colli} according to the collision rate
 - sends urgent lane change requests (ULCRs) to recommend the ego vehicle to perform a LC when a risk or an emergency around ego vehicle is detected



III. SIMULATION SCENARIO

- 4-km circular highway with maximum allowed speed equals 100 km/h
- Authentic dataset: Next Generation Simulation Vehicle Trajectories and Supporting Data
- Krauss mobility model for longitudinal control for all vehicles
- GL-DEAR LC model for the ego vehicle and NGSIM LC model for ordinary vehicles
- Simulator: SUMO (Simulation of Urban MObility)
- Baselines: KNN, DNN, LC2013, Policy Gradient, DEAR



V2D: vehicle-to-drone communication
D2E: drone-to-ego communication

IV. RESULTS

TABLE I
PERFORMANCE TEST RESULTS IN SPARSE TRAFFIC

| Model | KNN | DNN | LC2013 | PG | DEAR | GL-DEAR |
|------------------|------|------|--------|-------|-------|---------|
| Collision Number | 0 | 0 | 0 | 0 | 0 | 0 |
| LC Request | 0.6 | 23 | 31.5 | 544 | 353.3 | 477 |
| Avg Speed (km/h) | 29.9 | 46.3 | 60.9 | 60.8 | 65 | 58.6 |
| t_r (s) | 26.1 | 22.8 | 14.4 | 19 | 5.6 | 4.7 |
| t_b (s) | 83.3 | 22.8 | 66.4 | 100.4 | 68.7 | 50.1 |

TABLE II
PERFORMANCE TEST RESULTS IN MEDIUM TRAFFIC

| Model | KNN | DNN | LC2013 | PG | DEAR | GL-DEAR |
|------------------|-------|------|--------|-------|-------|---------|
| Collision Number | 0 | 0 | 0 | 0 | 0 | 0 |
| LC Request | 69 | 34.7 | 44.2 | 782.5 | 284.3 | 516 |
| Avg Speed (km/h) | 33.8 | 47.3 | 60 | 61.6 | 67.1 | 53 |
| t_r (s) | 29.1 | 29.6 | 25.1 | 46 | 10.9 | 7.7 |
| t_b (s) | 131.6 | 66 | 166.8 | 172 | 116 | 83 |

TABLE III
PERFORMANCE TEST RESULTS IN DENSE TRAFFIC

| Model | KNN | DNN | LC2013 | PG | DEAR | GL-DEAR |
|------------------|-------|-------|--------|-------|-------|---------|
| Collision Number | 0 | 0 | 0 | 0 | 0 | 0 |
| LC Request | 44.3 | 65.5 | 202.2 | 717 | 296.8 | 466 |
| Avg Speed (km/h) | 44 | 47.1 | 56.5 | 55.4 | 65 | 49.4 |
| t_r (s) | 46.2 | 38.7 | 20.7 | 26.4 | 19.9 | 8.1 |
| t_b (s) | 248.2 | 178.3 | 82 | 315.6 | 106.5 | 75.8 |

TABLE IV
PERFORMANCE WITH DIFFERENT n_{safe}

| Vehicle Number, nv | 50 | | | 150 | | | 250 | | |
|--------------------|------|------|------|------|-----|------|------|------|------|
| | 1 | 3 | 5 | 1 | 3 | 5 | 1 | 3 | 5 |
| Avg Speed (km/h) | 56 | 58.6 | 60.7 | 52.5 | 53 | 55.3 | 45.9 | 49.4 | 49.6 |
| Risky Time (s) | 5.2 | 4.7 | 18.5 | 41.7 | 7.7 | 13.8 | 5.6 | 8.1 | 9.2 |
| Blocking Time (s) | 47.3 | 50.1 | 64.4 | 65.6 | 83 | 90.9 | 94.4 | 75.8 | 85.9 |

n_{safe} in TABLE IV is a predefined threshold, according to which the ego vehicle switches between safety mode and efficiency mode

V. CONCLUSION AND PROSPECTS

1. We implemented a GL-DEAR LCA platform which:
 - enhances road active safety
 - takes into account risky roads and emergency vehicles with different traffic densities
2. LC decision should be made in a tight time window
 - We envision to adopt Federated Learning distributed on clients and controlled by the drones