Global Dynamic Drone Assisted Lane Change Maneuver for Risk Prevention and Collision Avoidance

Presented by Jialin HAO

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Supervised by Rola Naja and Djamal Zeghlache

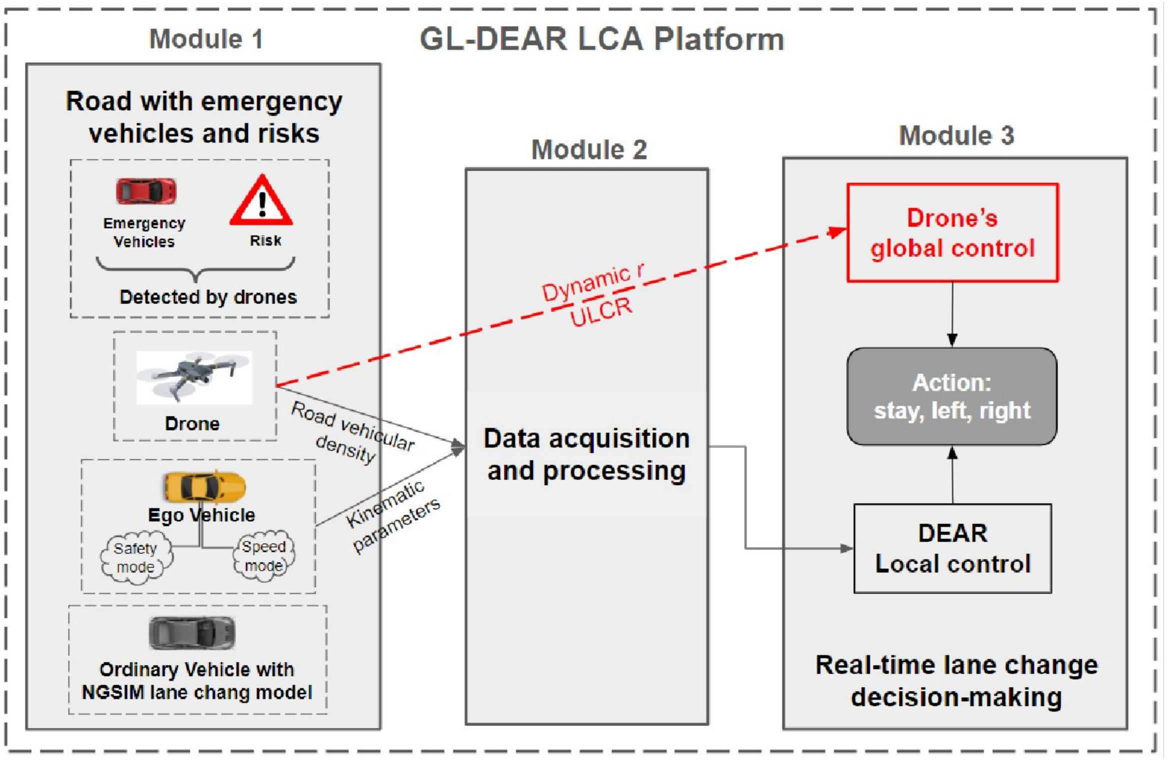
I. MOTIVATION

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

- Thesis context:
    - DigiCosme: ANR11LABEX 0045 DIGICOSME
    - DataWaves project: DATA-Driven Framework for Active Safety In Intelligent Transportation Systems

II. GL-DEAR PLATFORM



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

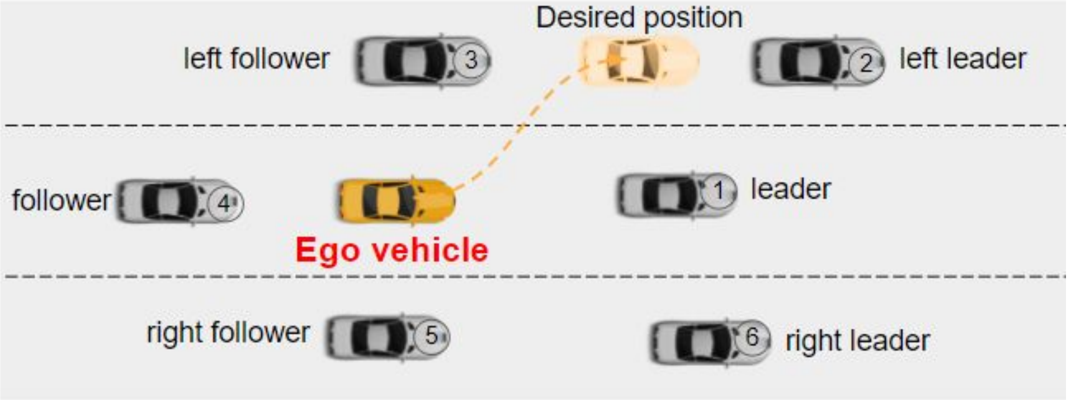
$$R = w_{comf}R_{comf} + w_{eff}R_{eff} + w_{safe}R_{safe}$$

- 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



- Action space: $a = \{0, 1, 2\}$, representing
  - staying in current lane
  - LC to the right
  - LC to the left

- State space: $o[j] = \{o_{ego}[j], o_1[j], \cdots, o_6[j]\}$, 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

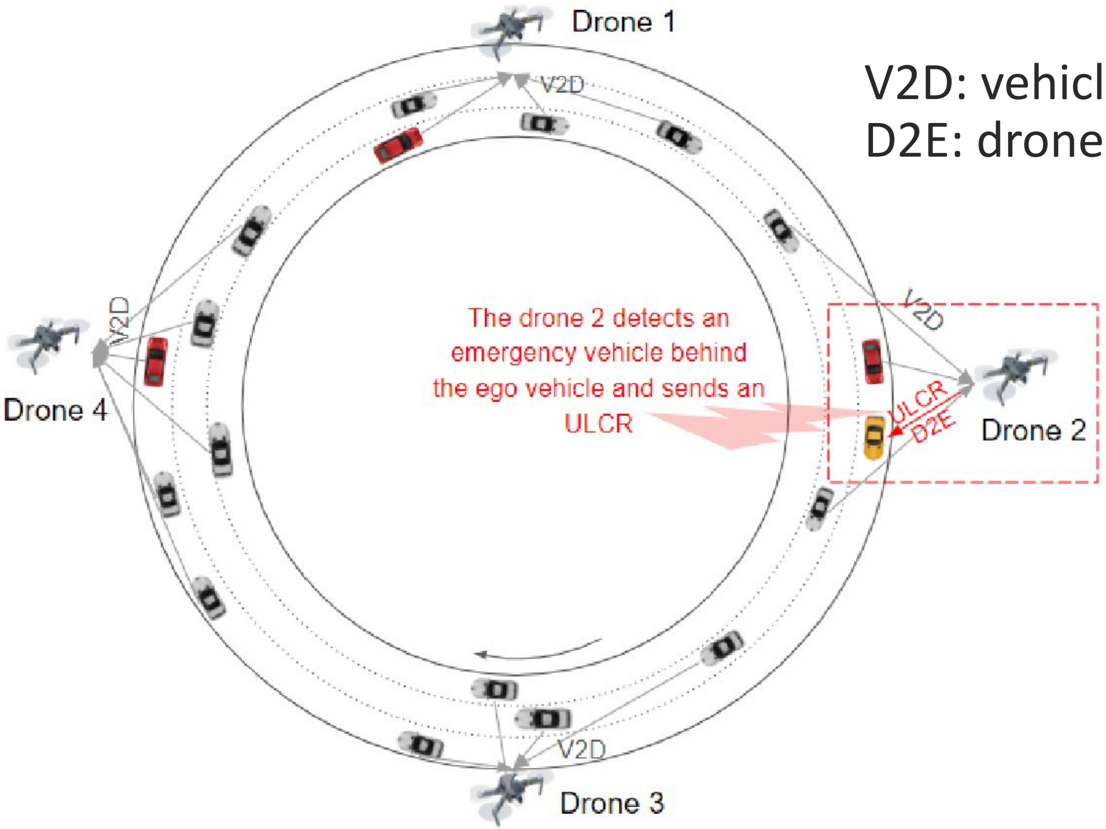
II-3. DRONES PLAY AN IMPORTANT ROLE IN RISK PREVENTION AND COLLISION AVOIDANCE

- 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

III. SIMULATION SCENARIO

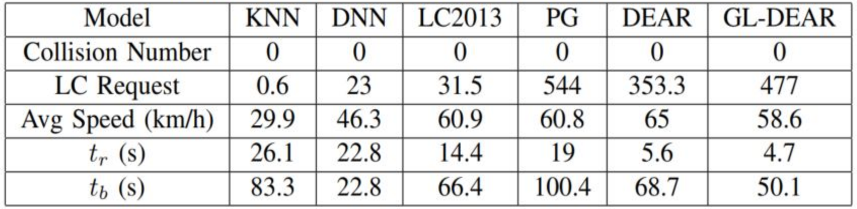


V2D: vehicle-to-drone communication
D2E: drone-to-ego communication

IV. RESULTS

TABLE I

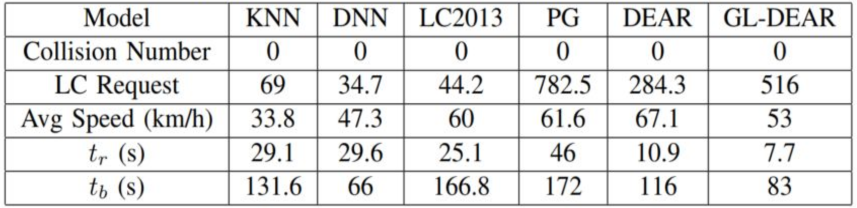
PERFORMANCE TEST RESULTS IN SPARSE TRAFFIC



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

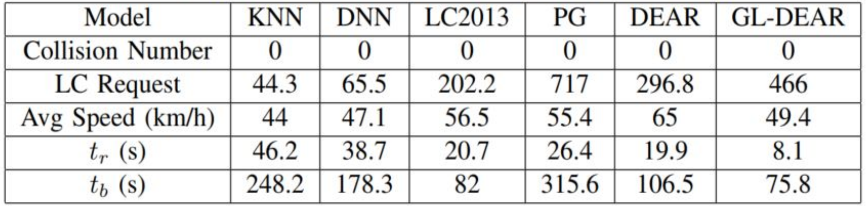
PERFORMANCE TEST RESULTS IN MEDIUM TRAFFIC



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

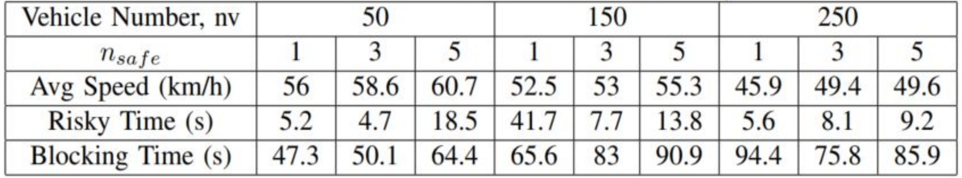
PERFORMANCE TEST RESULTS IN DENSE TRAFFIC



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		
n_{safe}	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

PUBLICATIONS

1. Jialin Hao, Rola Naja, Djamal Zeghlache, “GL-DEAR: Global Dynamic Drone Assisted Lane Change Maneuver for Risk Prevention and Collision Avoidance,” accepted by IEEE International Conference on Communications (ICC), May 2023, Italy
2. Jialin Hao, Rola Naja, Djamal Zeghlache, “Drone-Assisted Lane Change Maneuver using Reinforcement Learning with Dynamic Reward Function,” IEEE 18th International Conference on Wireless and Mobile Computing, Networking and Communications (IEEE WiMob), October 2022, Greece
3. Jialin Hao, Rola Naja, Djamal Zeghlache, “Joint Local Reinforcement Learning Agent and Global Drone Cooperation for Collision-Free Lane Change,” In proceedings of Springer 3rd EAI International Conference on Computational Intelligence and Communications (Springer EAI CICom), December 2022, Virtual

Thanks!