MACHINE LEARNING FOR ROAD ACTIVE SAFETY

GLOBAL DYNAMIC DRONE ASSISTED LANE CHANGE MANEUVER FOR RISK PREVENTION AND COLLISION AVOIDANCE

TELECOM SudParis · IP PARIS · s@movar · Institut Mines-Télécom

Auteurs

Jialin HAO

Rola NAJA

Djamal ZEGHLACHE

Partenaires

Labex DigiCosme — université PARIS-SACLAY

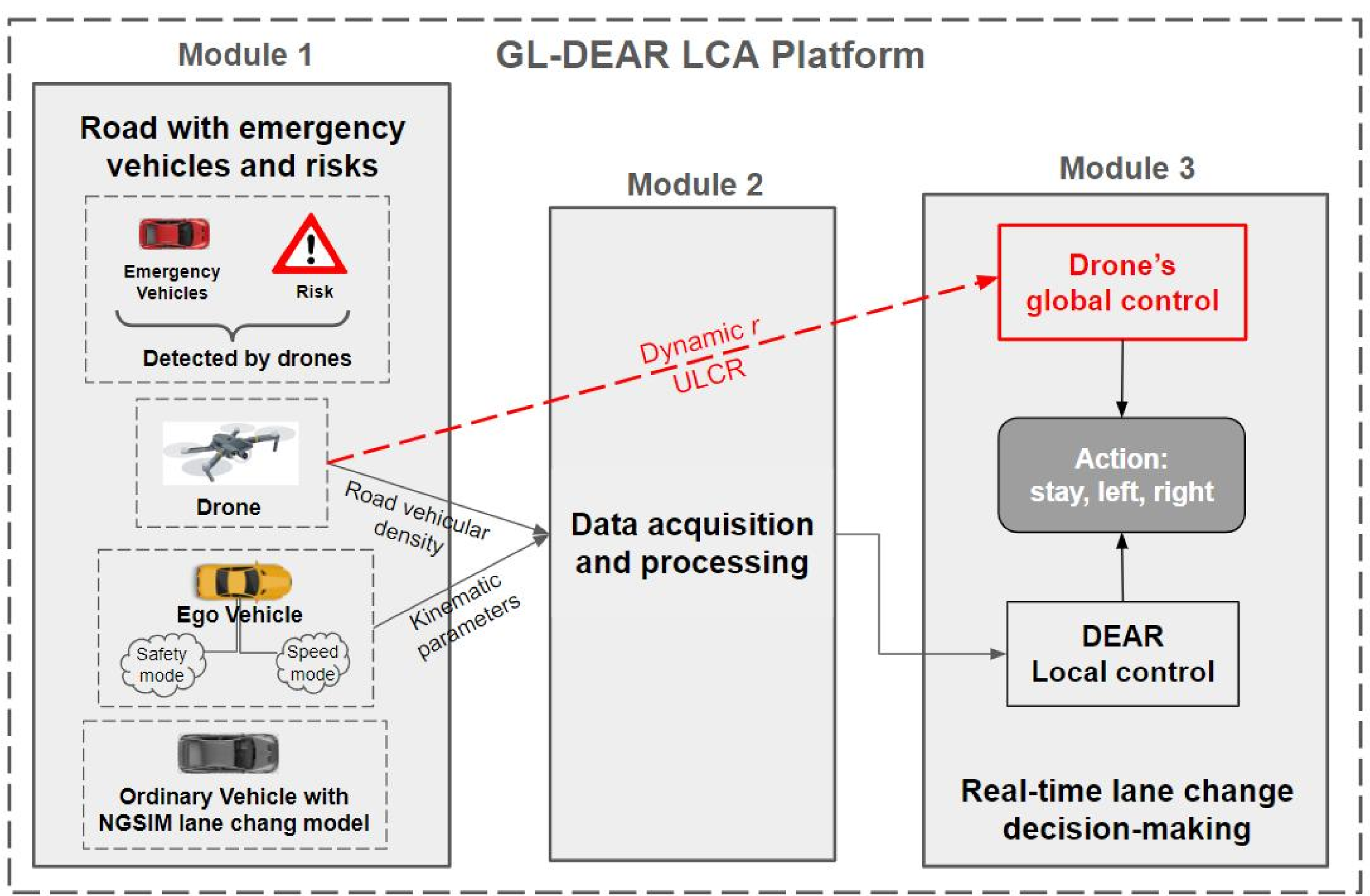
ECE — ÉCOLE D'INGÉNIEURS ENGINEERING SCHOOL

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

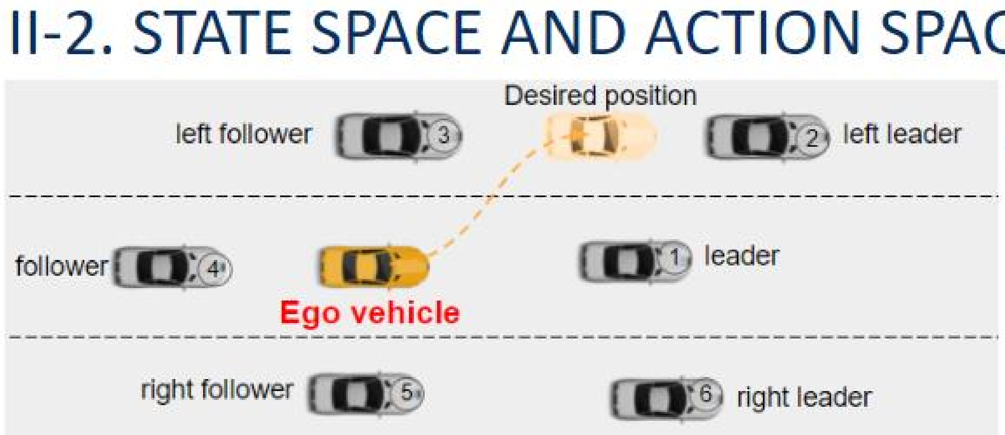
$$R = w_{comf}R_{comf} + w_{eff}R_{eff} + w_{safe}R_{safe}$$

- 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



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

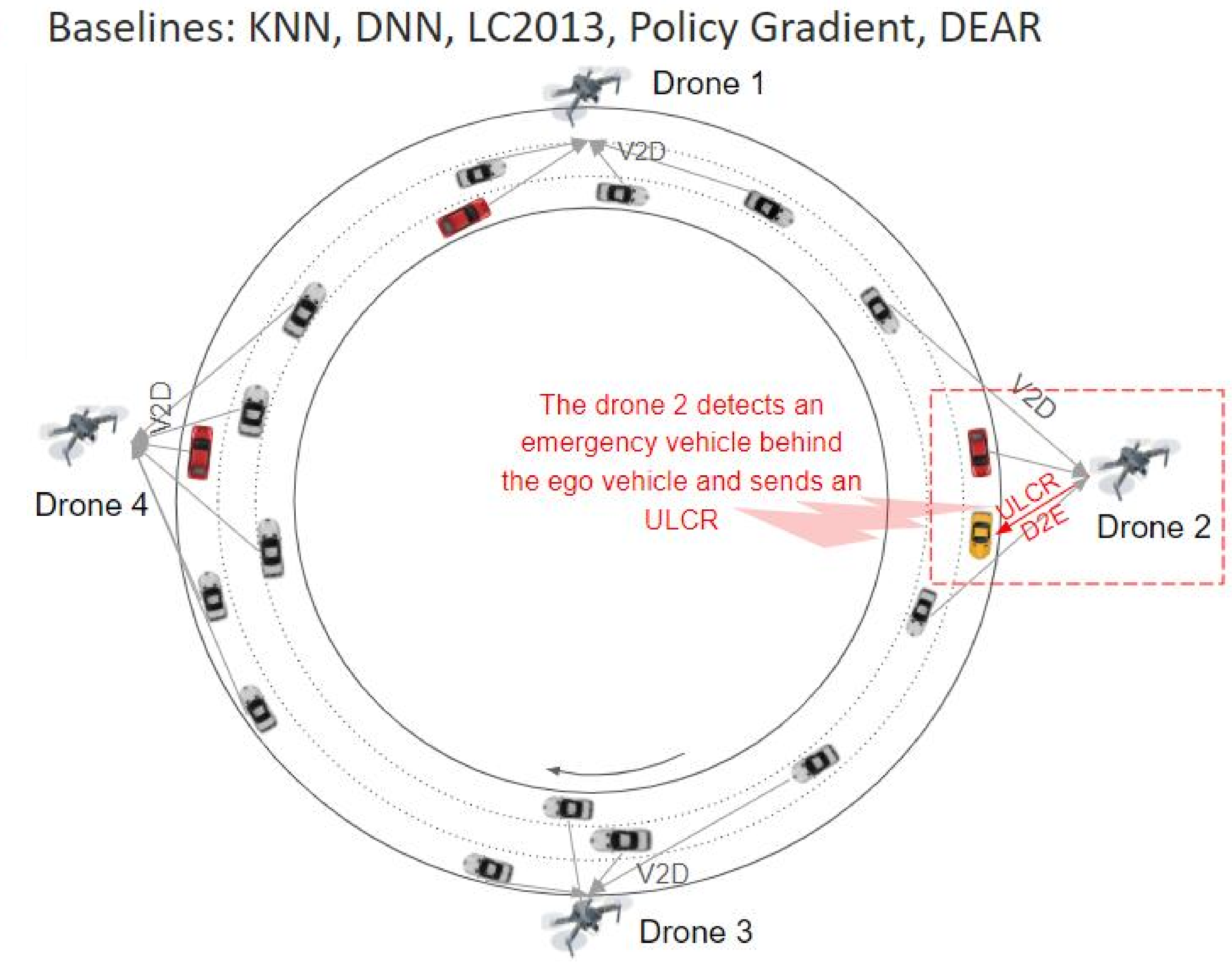
- State space: $o[j] = \{o_{ego}[j], o_1[j], \cdots, o_6[j]\}$, where:
  - $o_{ego}[j] = \{l_{risk}[j], x_{ego}[j], y_{ego}[j], v_{ego}[j], a_{ego}[j], l_{ego}[j]\}$ contains road risk label, kinematic parameters and current lane id of the ego vehicle at step j
  - $o_i[j] = \{x_i[j], y_i[j], v_i[j],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



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. 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

Samovar Doctoral Day

March 2023

Contact jialin.hao@telecom-sudparis.eu

www.researchgate.net/profile/Jialin-Hao