CONSTRAINED MULTI CAMERA CALIBRATION FOR LANE MERGE OBSERVATION

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5GCAR EU Project

5G Communication **A**utomotive **R**esearch and Innovation
H2020 5G PPP Phase 2 Project Funded by the European Commission

- 5G V2X system focused on highly accurate positioning, large bandwidths
- Demonstrations in vehicular applications

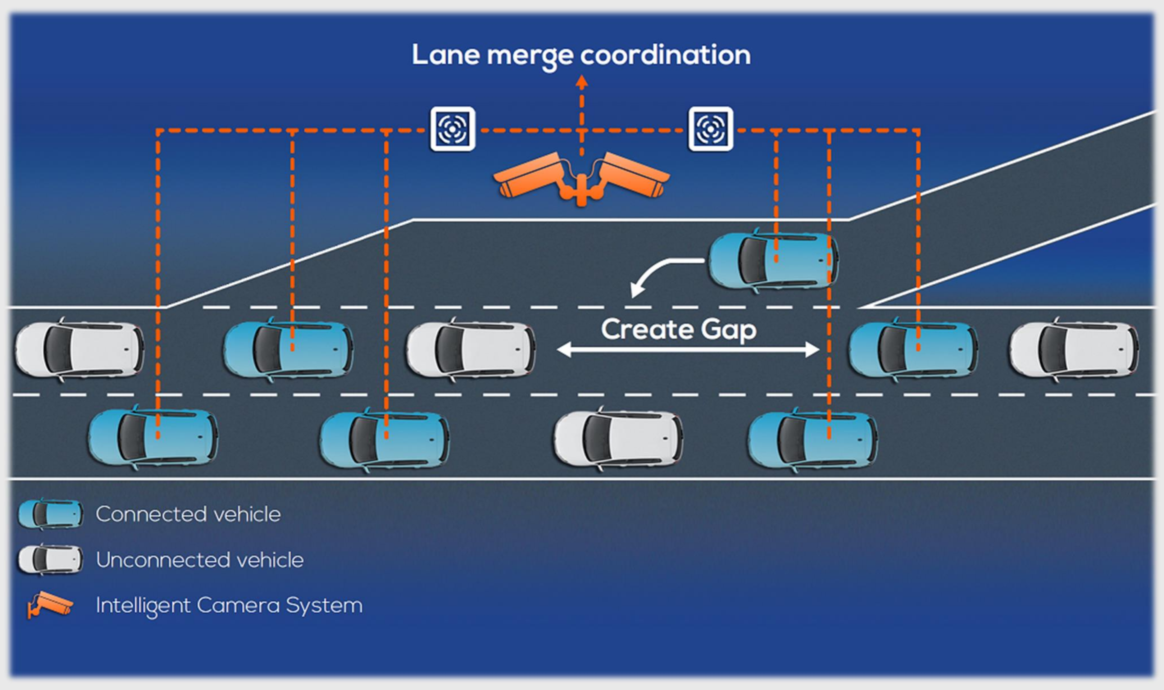
Lane Merge Coordination

5GCAR Use Case: Automated Driving, Cooperative Maneuver

- Coordination of trajectory recommendations
- Localization of connected and unconnected vehicles

Camera Based Localization of Vehicles

- **Requirements:** large observation area, distances up to 300m
- ➢ Highly accurate multi camera calibration



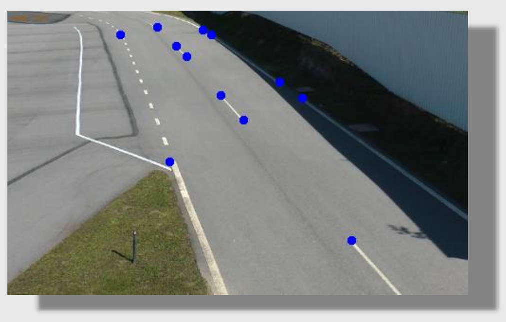
Constrained Multi Camera Calibration

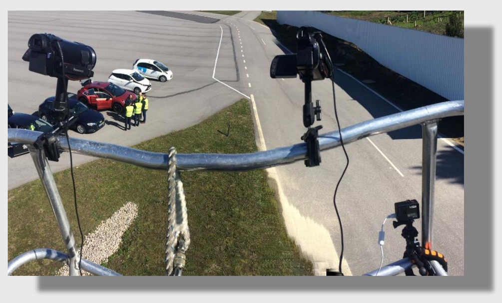
2D - 3D Correspondences $\mathbf{p}_{j,k} \longleftrightarrow \mathbf{P}_j$ for Cameras A_k

- Accurately measured landmarks (RTK-GPS)
- Manually annotated 2D positions

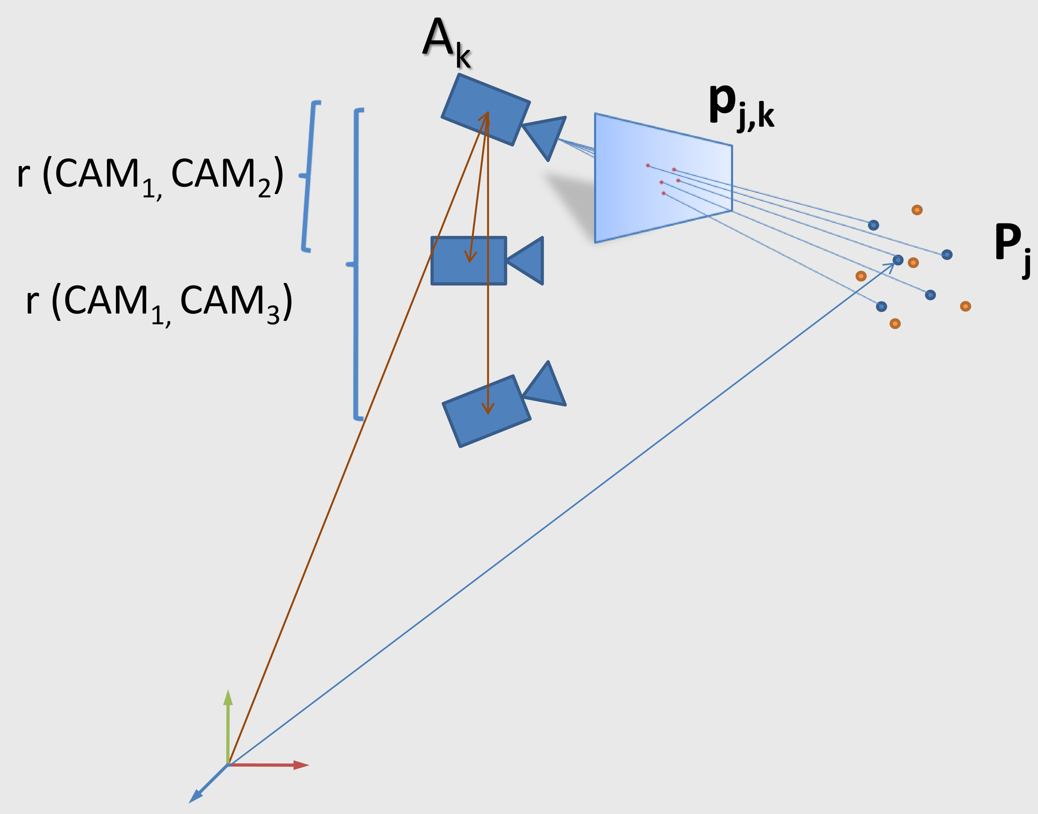
Proposed Multi Camera Calibration

- Incorporation of relative camera distances r
  - ➢ Reduction of search space dimension
- Global optimization using differential evolution





Set(1)



Experimental Results

Camera Positions Evaluation

h_i: height of CAM_i

r_i: distance to CAM_1

h_{gt}, r_{gt}: ground truth

e: mean error

		CAM_1	CAM_2	CAM_3	CAM_4	e	
Exp_1:	h_1	8.09	7.85	7.13	7.05	0.30	Single Camera Optimization
	r_1	--	1.81	1.38	1.73	0.44	
Exp_2:	h_2	set to ground truth h_{gt}				--	
	r_2	--	1.97	1.02	1.28	0.45	
Exp_3:	h_3	7.59	7.59	7.12	7.11	0.14	Multi Camera Optimization
	r_3	--	0.93	1.26	1.56	0.27	
Exp_4:	h_4	**7.57**	**7.57**	**6.94**	**7.11**	**0.10**	
	r_4	--	set to ground truth r_{gt}			--	
	h_{gt}	7.63	7.63	6.65	7.10	--	Ground Truth
	r_{gt}	--	0.77	1.62	1.27	--	

Set(1) [m]

		CAM_1	CAM_2	CAM_3	CAM_4	e	
Exp_1:	h_1	4.49	6.69	4.21	4.48	1.12	Single Camera Optimization
	r_1	--	14.18	8.67	3.33	7.98	
Exp_2:	h_2	set to ground truth h_{gt}				--	
	r_2	--	7.96	7.44	3.35	5.50	
Exp_3:	h_3	5.03	5.03	5.26	4.92	0.44	Multi Camera Optimization
	r_3	--	1.83	4.34	1.69	1.87	
Exp_4:	h_4	**5.48**	**5.48**	**5.70**	**5.32**	**0.09**	
	r_4	--	set to ground truth r_{gt}			--	
	h_{gt}	5.51	5.51	5.53	5.44	--	Ground Truth
	r_{gt}	--	0.32	1.40	0.52	--	

Set(3) [m]

Conclusions

Proposed Method: Calibration of Multi Camera Setup
➢ Incorporation of constrains increases accuracy
Evaluation on Test Track: Camera Height Estimation Error < 0.10 m
➢ Accurate benchmark data sets: video data, camera calibration, vehicle localization

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