Enhanced Radar Detection: Semantic Cluster and Track Management for Ghost Suppression ——Implementation Details

A. Implementation Details

TABLE 1. MMCAS-RF-EVM Radar Data Sheet.

Description	Value
Number of TX antennas	12
Number of RX antennas	16
Carrier Frequency	77 GHZ
Bandwidth	76 - 81 GHz
ADC Sampling Rate	45 MHZ
FPS	10
Frame Duration	100 ms
Maximum Range	150 m
Range Resolution	0.06 m
Horizontal FOV	120 °
Elevation FOV	90 °
Horizontal Angle Resolution	1.4 °
Elevation Angle Resolution	18 °
Maximum Velocity	37 m/s
Velocity Resolution	0.15 m/s
Transceiver	FMCW

TABLE 2. Dynamic Capture System Data Sheet.

	Description	Value
Image Sensor	Pixels	1.3M
	Resolution	1280×1024
	Frame Rate@Full Resolution	180FPS
	Frame Rate@Partial Resolution	Not Supported
	Frame Rate Adjustment	Adjustable
	Latency (ms)	5.5
	Type of Exposure	Global
	Exposure Speed	Settable
Track Performance and Range	Accuracy	±0.4 mm
	Observation Distance (with 15mm diameter markers)	8 m
	Active Marker Supported	Yes
Camera	Lens Specification	5.3 mm
	Field of View (FOV)	56 °×46 °
	Aperture Adjustable	No
	Focus Adjustable	Yes
LEDs	Number	14
	Type	HLED
	Brightness Adjustable	Yes
	Wavelength	850 nm
Interface and Power Supply	Connection Type	GigE/POE
	Power Consumption	18 W
	Sync Interface	RCA
	Sync Signal Output	Optional
Product Appearance and Operating Conditions	Shell Material	Metal
	Size	62 ×62×96 mm
	Weight	0.3 Kg
	Mounting Hole	1/4 "
	Number of Mounting Holes	2
	Temperature Range	-20 ℃ to 65 ℃
	Humidity	< 80%
	Outdoor	No

TABLE 3. Hyper-parameters of the proposed method.

	Description	Value
Semantic Scene Restriction	Used to ignore points cloud with very low radial velocity. v_{Thre}	0.1 m/s
	DBSCAN radius. ϵ	0.5 m
	DBSCAN minimum cluster points. m_{pts}	15
	KDE kernel function	Gaussian kernel
	KDE density threshold. θ	25 %
Overall Semantic Segmentation	**MSG and FP**	
	MLPs (1st MSG layer)	[[32, 32, 64], [64, 64, 128]]
	MLPs (2nd MSG layer)	[[32, 32, 64], [64, 64, 128]]
	MLPs (3rd MSG layer)	[[64, 64, 128], [64, 64, 128]]
	MLP (1st FP module)	[256, 256]
	MLP (2nd FP module)	[128, 128]
	MLP (3rd FP module)	[128, 128, 128]
	Final Conv Layers	
	Conv1	$128 \rightarrow 256$
	Conv2	$256 \rightarrow 128$
	Conv3	$128 \rightarrow 3$
	Optimization Parameters	
	Optimizer	Adam
	Learning rate	0.0001
	Betas for Adam optimizer	(0.9, 0.999)
	Epsilon	1e-08
	Weight decay (L2 regularization)	1e-4
	Training Parameters	
	Batch size (train)	1000
	Number of epochs	50
	Number of classes. n	3 (Pedestrian, Vehicle, Ghost)
	Input Data	
	Input channels	5 (x, y, z, v, RCS)
Tracker and Data Association	Process noise of EKF. Q	$\begin{bmatrix} \frac{T^3}{3} & 0 & \frac{T^2}{2} & 0 \\ 0 & \frac{T^3}{3} & 0 & \frac{T^2}{2} \\ \frac{T^2}{2} & 0 & T & 0 \\ 0 & \frac{T^2}{2} & 0 & T \end{bmatrix}$
	Observation noise of EKF. R	$\mathrm{diag}(0.06^2, 0.06^2, 0.15^2)$
	The time step between frames, i.e., time for five radar scans. T	0.5 s
	The distance gate. G	$\|[1, 1, 1]^T\| = 1.73$
Fusion Management	Max skipped frames. m_{skip}	3
	Min initial track frames. $m_{initial}$	5

Table 1 shows the complete MMCAS-RF-EVM[1] Radar data sheet. It is necessary to clarify that we only use the Dynamic Capture System to help annotate our dataset and obtain the precise location of the real targets. Dynamic Capture System is a precise positioning system based on capturing reflective signals using cameras. The reflective signals of the system are provided by reflective sensors (red rectangles) attached on the target surface, as shown Fig.1. Pedestrians need to wear a special hat as seen in the left panel, while for vehicles, we directly attach the reflective sensors to their surface as shown in the right panel. After this, the Dynamic Capture System can obtain the

[1] https://www.ti.com/tool/MMWCAS-RF-EVM

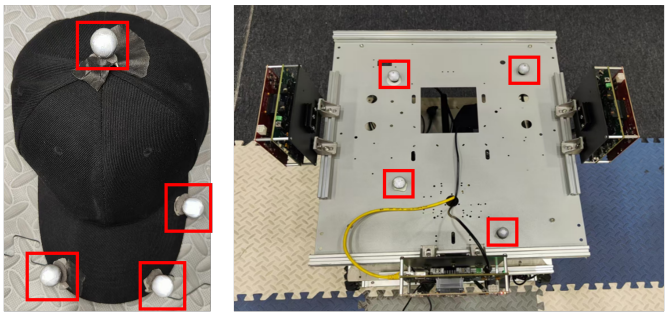

Fig. 1. Reflective sensors (red rectangle).

precise location of real targets in real time. We use the PLUTO 1.3C[2] Dynamic Capture System from NOKOV company. Table 2 shows the complete data sheet for the device.

[2]https://en.nokov.com/products/motion-capture-cameras/Pluto.html