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SIGNAL PROCESSING IN UNMANNED VEHICLES (ADAS) WITH MATLAB

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Advanced Driver Assistance Systems (ADAS) in unmanned vehicles rely on robust signal processing techniques to interpret sensor data and make critical navigation decisions. This paper examines key MATLAB implementations for ADAS applications.

Unmanned vehicles employ multiple sensors including radar, LiDAR, and cameras, each producing signals with distinct characteristics. Radar signals can be modeled as:

$$s(t) = A \cdot exp(j2\pi f_c t + j\pi\gamma t^2)$$

where A is amplitude, f_c is center frequency, and γ is chirp rate. In MATLAB:

```
fc = 77e9;                    % Center frequency (77 GHz)
chirpSlope = 21e12;       % Chirp slope in Hz/s
sampleRate = 200e6;    % Sample rate
t = 0:1/sampleRate:40e-6-1/sampleRate;
signal = exp(1j*2*pi*(fc*t + chirpSlope*t.^2/2));
```

Raw sensor data requires filtering before further processing. The Kalman filter is effective for tracking applications:

$$\hat{x}_k = \hat{x}_k - 1 + \mathrm{K}_k(\mathrm{z}_k - \mathrm{H}\hat{x}_{k-1})$$

where $\hat{x}_k$is the estimated state, K_k is Kalman gain, z_k is measurement, and H is observation matrix.

For non-stationary signals common in vehicle environments, time-frequency analysis provides valuable insights. The Short-Time Fourier Transform (STFT) offers a balance between time and frequency resolution:

$$\mathrm{STFT}\{x(t)\}(\tau, \omega) = \int_{-\infty}^{\infty} x(t)w(t-\tau)e^{-j\omega t dt}$$

where w(t) is the window function. Implemented in MATLAB as:

```
windowLength = 256;
overlap = 128;
[S, F, T] = spectrogram(signal, hamming(windowLength), overlap, 512, sampleRate);
```

Wavelet analysis excels at detecting transient phenomena:

$$W_x(\mathrm{a}, \mathrm{b}) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{\infty} x(t)\psi^*(\frac{t-b}{a})dt$$

where ψ is the mother wavelet, a is scale parameter, and b is translation parameter.

Effective ADAS relies on fusing data from multiple sensors to create a comprehensive environmental model. The Bayesian fusion framework provides:

$$p(x \mid z_1, z_2) \infty\, p(z_1 \mid x)\; p(z_2 \mid x)\; p(x)$$

assuming conditional independence of measurements. For nonlinear vehicle dynamics, the Extended Kalman Filter (EKF) is necessary:

$$\hat{x}_k = f(\hat{x}_{k-1}) + K_k(z_k - h(f(\hat{x}_{k-1})))$$

where f and h are nonlinear functions, linearized via Jacobians.

Modern ADAS relies on object detection and classification, typically implemented using Convolutional Neural Networks (CNNs). Path planning algorithms must process sensor data to generate safe trajectories. The Rapidly-exploring Random Tree (RRT) algorithm provides an efficient approach.

ADAS systems must process signals in real time under strict latency constraints. MATLAB offers optimization strategies including array preallocation, vectorization, and MEX functions for critical sections. Deployment to embedded systems is supported through automatic code generation:

```
cfg = coder.config('lib');
cfg.TargetLang = 'C++';
codegen -config cfg signalProcessingPipeline.m -args {zeros(1000,1)}
```

Performance metrics include detection rate and false alarm rate:

$$\text{Detection Rate} \frac{\text{Number of Correct Detections}}{Total\ Number\ of\ Objects}$$

Signal processing forms the backbone of modern ADAS systems, enabling reliable perception, decision-making, and control. MATLAB provides a comprehensive ecosystem for developing and deploying these critical algorithms. Future work should focus on integrating deep learning with traditional signal processing techniques to enhance robustness while maintaining real-time performance.

List of sources used:

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