Navigating the Signal: ECG Data Filter Algorithms

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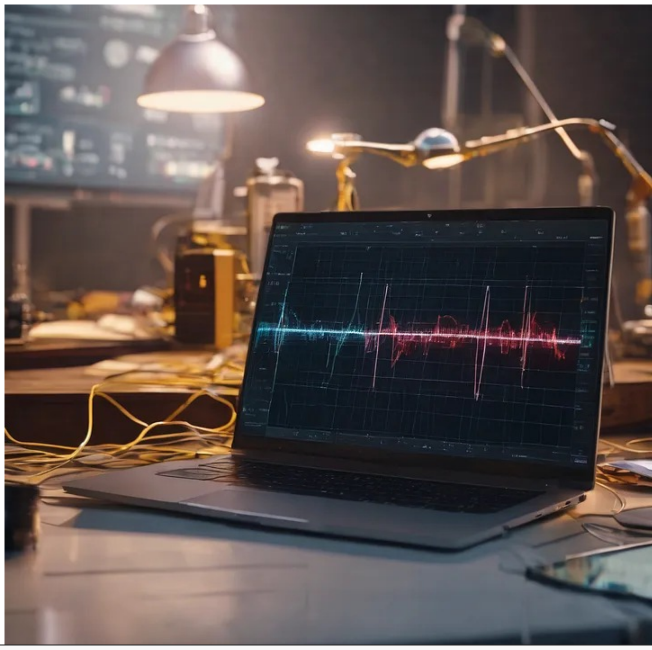

algorithms and their Python implementations.

1. Linear Filters

Linear filters modify signals based on a linear combination of input samples. We'll implement a basic low-pass filter using the convolution operation.

```
import numpy as np
import matplotlib.pyplot as plt

def low_pass_filter(signal, cutoff_freq, sampling_freq):
    # Designing filter kernel
    t = np.arange(-10, 10, 1/sampling_freq)
    kernel = np.sinc(2 * cutoff_freq * t)
    kernel /= np.sum(kernel)

    # Convolve signal with filter kernel
    filtered_signal = np.convolve(signal, kernel, mode='same')
    return filtered_signal

# Sample ECG signal (replace with actual data)
sampling_freq = 1000  # Hz
t = np.arange(0, 10, 1/sampling_freq)
ecg_signal = np.sin(2 * np.pi * 10 * t) + 0.5 * np.sin(2 * np.pi * 20 * t)
```

```
# Apply low-pass filter
cutoff_freq = 15  # Hz
filtered_ecg = low_pass_filter(ecg_signal, cutoff_freq, sampling_freq)

# Plot original and filtered signals
plt.figure(figsize=(10, 5))
plt.plot(t, ecg_signal, label='Original ECG')
plt.plot(t, filtered_ecg, label='Filtered ECG')
plt.xlabel('Time (s)')
plt.ylabel('Amplitude')
plt.title('ECG Signal with Low-pass Filtering')
plt.legend()
plt.grid(True)
plt.show()
```

2. Adaptive Filters
Adaptive filters adjust parameters based on input signals, making them effective in non-stationary environments. Let's implement a basic LMS adaptive filter to remove noise.

```
from scipy.signal import lfilter

def adaptive_filter(signal, noise, mu=0.01, order=4):
    filtered_signal, _, _ = lfilter([mu] * order, 1, signal, zi=noise)
    return filtered_signal

# Generate noisy ECG signal (replace with actual data)
noise = np.random.normal(0, 0.5, len(ecg_signal))

# Apply adaptive filtering
filtered_ecg_adaptive = adaptive_filter(ecg_signal, noise)

# Plot original and adaptively filtered signals
plt.figure(figsize=(10, 5))
plt.plot(t, ecg_signal, label='Original ECG')
plt.plot(t, filtered_ecg_adaptive, label='Adaptive Filtered ECG')
plt.xlabel('Time (s)')
plt.ylabel('Amplitude')
plt.title('ECG Signal with Adaptive Filtering')
plt.legend()
plt.grid(True)
plt.show()
```

3. Wavelet Transform-Based Filters
Wavelet transforms decompose signals into frequency components, aiding noise removal while preserving features. Let's use the PyWavelets library for wavelet denoising.

```
import pywt

def wavelet_denoise(signal, wavelet='db4', level=3):
    coeffs = pywt.wavedec(signal, wavelet, level=level)
    threshold = np.sqrt(2 * np.log(len(signal)))
    coeffs = [pywt.threshold(c, threshold, mode='soft') for c in coeffs]
    denoised_signal = pywt.waverec(coeffs, wavelet)
    return denoised_signal

# Apply wavelet denoising
denoised_ecg_wavelet = wavelet_denoise(ecg_signal)

# Plot original and denoised signals
plt.figure(figsize=(10, 5))
plt.plot(t, ecg_signal, label='Original ECG')
plt.plot(t, denoised_ecg_wavelet, label='Denoised ECG (Wavelet)')
plt.xlabel('Time (s)')
plt.ylabel('Amplitude')
plt.title('ECG Signal with Wavelet Denoising')
plt.legend()
plt.grid(True)
plt.show()
```

Python provides powerful tools for implementing and visualizing ECG data filtering algorithms. By applying these techniques, healthcare professionals can enhance diagnostic accuracy and improve patient care outcomes in cardiac monitoring and analysis. Experimenting with various algorithms and parameters can further refine the filtering process, ensuring optimal signal quality for clinical interpretation.

Ecg Filtering Algorithms

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