Learning Resource: IMU Data Filtering

Krutarth e-Yantra Staff Dec 2023

Why is this required?

The IMU is a tiny sensor module that gives us orientation related feedback. The gyroscope & accelerometer that are present inside the IMU provide the data we want, but there's also a significant noise, drift & lag in the data most of the times.

To overcome the effects of these, one should learn and implement some signal processing on the IMU data before feeding that to the control algorithm.

Introduction to sensor fusion for IMU

There's a nice video to get an intuition about why does an IMU require sensor fusion?

Signal processing for sensor fusion

In signal processing, a "Filter" is a device or process that removes some unwanted components or features from a signal. Filtering is a class of signal processing, the defining feature of filters being the complete or partial suppression of some aspect of the signal. Most often, this means removing some frequencies or frequency bands.

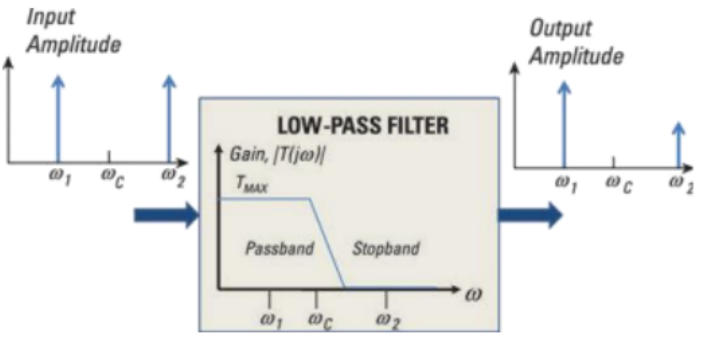
There are many different bases of classifying filters and these overlap in many different ways; there is no simple hierarchical classification. Filters maybe: Non-Linear or Linear, Time-variant or Time-invariant, Causal or Not-causal, Analog Or Digital, Passive or Active etc……

Frequency filter circuits *(such as low-pass, high-pass, band-pass, and band-reject)* shape the frequency content of signals by allowing only certain frequencies to pass through. .

Skip to main content

1. Low Pass Filter

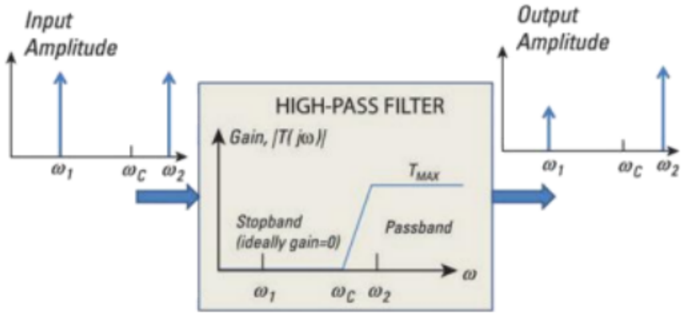
The low-pass filter has a gain response with a frequency range from zero frequency(DC) to cutoff frequency (ωc), which means that any input that has a frequency below the ωc gets a pass, and anything above it gets attenuated or rejected. The gain approaches zero as frequency increases to infinity. Refer to the image below:



The input signal of the filter shown here has equal amplitudes at frequencies ω1 and ω2. After passing through the low-pass filter, the output amplitude at ω1 is unaffected because it’s below the cutoff frequency ωc. However, at ω2, the signal amplitude is significantly decreased because it’s above ωc.

2. High Pass Filter

Opposite to the Low-pass filter, the high-pass filter has a gain response with frequency range from the cutoff frequency (ωc) to infinity. Any input having a frequency below ωc gets attenuated or rejected. Anything above ωc passes through unaffected. Refer to the image below:



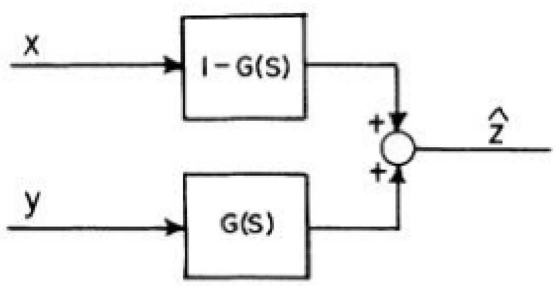
The input signal of the filter shown here has equal amplitude at frequencies ω1 andω2. After passing through the high-pass filter, the output amplitude at ω1 significantly decreases because it’s below ωc, and at ω2, the signal amplitude passesthrough unaffected because it’s above ωc.

3. Complementary Filter

Skip to main content

Complementary filter is a simple estimation technique to combine measurements. The Basic complementary filter is shown in the figure below where x and y are noisy measurements of signal z; Ẑ is the estimate of z produced by the filter.

- Assume that the noise in y is mostly high frequency, and the noise in x is mostly low frequency. Then G(s) can be made a low pass filter to filter out the high-frequency noise in y.
- If G(s) is low-pass, [1-G(s)] is the complement, i.e., a high pass filter which filters out the low-frequency noise in x. No detailed description of the noise process is considered in complementary filtering.



Why do we need to use complementary filter in our task?

After studying the characteristics of both gyro and accelerometer, we know that they have their own strengths and weaknesses. The calculated tilt angle from accelerometer data has slow response time, while the integrated tilt angle from gyro data is subjected to drift over a period of time. In other words, we can say that the accelerometer data is useful for the long term while the gyro data is useful for the short term. Idea behind complementary filter is to take slow moving signals from an accelerometer and fast moving signals from a gyroscope and combine them. Complementary filter is designed in such a way that the strength of one sensor will be used to overcome the weakness of the other sensor which is complementary to each other.

- Accelerometer gives a good indicator of orientation in static conditions. Gyroscope Gives a good indicator of tilt in dynamic conditions. So the idea is to pass the accelerometer signals through a low-pass filter

and the gyroscope signals through high-pass filter and combine them to give the final rate.
- The key-point here is that the frequency response of the low-pass and high-pass filters add up to 1 at all frequencies. This means that at any given time the complete signal is subject to either low pass or high pass.

Equation for low-pass filter:

```
y[n] = (1-alpha).x[n] + alpha.y[n-1] //use
// x[n] is the pitch/roll/yaw that you get
//y[n] is the filtered final pitch/roll/ya
//n is the current sample indicator.
```

Equation for high-pass filter:

```
y[n] = (1-alpha).y[n-1] + (1-alpha)(x[n]-x
//x[n] is the pitch/roll/yaw that you get
//y[n] is the filtered final pitch/roll/ya
//n is the current sample indicator.
```

A quick way of implementing a complementary filter:

```
angle = (1- alpha)(angle + gyro * dt) + (a
```

1st reading is the angle as obtained from gyroscope integration. 2nd reading the one from the accelerometer.

How to choose alpha(proportion) ?

```
alpha = (tau)/(tau + dt) //  where tau is
//(how fast you want the readings to respo
```

and

```
dt = 1/fs // where fs is your sampling fre
```

Related materials:

Topics
My Posts
More
Categories
Lunar Scout (LS)
Guidelines
ChatbotDocs
All categories
Tags
task-0
task-1
task-2
other
task-4
All tags
Skip to main content

https://vanhunteradams.com/Pico/ReactionWheel/Complementary_Filters.html

Lunar Scout: Task-4

Closed on Dec 15, 2023

Related Topics

Topic	Replies	Views	Activity
[PRACTICAL] Implementing control systems on Hardware!	3	315	Jan 30
Not able to tune yaw	3	63	Feb 13
Lunar Scout: Task-4	1	970	Nov 2023
[PRACTICAL] Recorded Session	2	158	Feb 10
[PRACTICAL] Misconceptions about CoM and Motors	6	271	Feb 20