**EE5410 Signal Processing**

**Miniproject 2**

**1. Objective**

In this miniproject we shall perform an interesting and useful application of multi-band (sometimes refer to as multi-channel, multi-bank or sub-band) filtering, namely, “image compression”.

在这个小项目中，我们将执行多频带（有时称为多通道、多组或子频带）滤波的有趣且有用的应用，即“图像压缩”

**2. Background of two channel sub-band coding**

A 2-channel multi-bank filter is shown in Figure 1. The transfer functions of the analyzing and synthesis filters are given as follows:

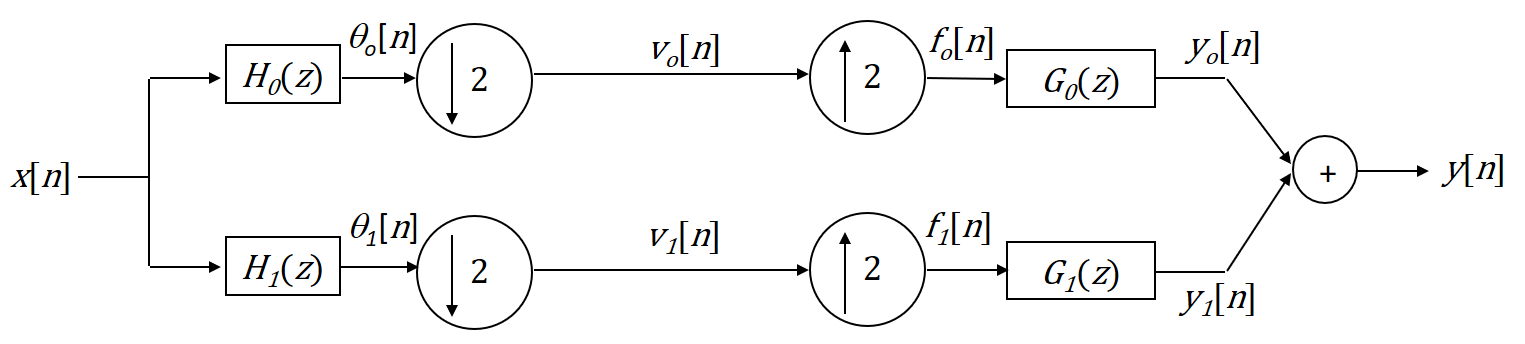
2 通道多组滤波器如图 1 所示。分析和合成滤波器的传递函数如下：

(a) , (low pass transfer function)

(b) , (high pass transfer function)

(c) , and

(d) .



**Figure 1**

Distortion (overall) Transfer Function:

 (1)

Aliasing term:

 (2)

Autocorrelation:

 is zero except for  (3)

(1) to (3) proved that the PR conditions are satisfied.

3. 压缩是如何实现的？

子带滤波器通常用于压缩。压缩端（又名编码器）将输入信号分解为两个或多个通道，每个通道的输出被重新量化或去除，然后存储或传输。

考虑图 1 中的 2 通道多组滤波器。假设每个样本中有 N 个输入样本，由每个样本 q 位 (bps) 表示。输入比特率为 Nq 比特。对于每个通道，抽取器的输出为 Nq/2 位。由于有 2 个通道，编码器后的总比特率仍然是 Nq 比特。换句话说，数据没有减少。压缩可以通过在抽取器和内插器之间用更少的比特重新量化数据（和）来实现，或者简单地移除一个通道。

4.简单的压缩类型

一种简单的压缩是去除信号信息较少的通道。对于图像和音频信号等数据，信息往往集中在低频端，而在高频端稀疏。因此，去除高频带会导致压缩而不会造成严重失真。然而，压缩信号的保真度不如在抽取器之后重新量化数据。

在给定的 PR 结构中，通道 1 和通道 2 分别对应于低通滤波器通道和高通滤波器通道。

简单的压缩类型是单独保留通道 1，即输入信号的低频段。

5. 基本成果

a) 基于图 1 中的一维 (1-D)、2 通道 PR 滤波器，用 Matlab 实现一个用于处理数字图像的二维 (2-D) PR 滤波器（参见注释“SIG4.pptx”）。

b) 给你两张用于测试的二维测试图片，你可以在 Canvas 中的“Miniproject 2”模块下下载。

c) 将源图像输入到 5(a) 中实现的 2-D PR 滤波器。在滤波器的输出图像上显示图像，并以分贝 (dB) 为单位确定其峰值信噪比 (PSNR) 的保真度。与源图像相比，您对输出图像的质量和数据大小有何结论？

关于使用 PSNR 比较一对图像，请参阅附录 A。

d) 通过丢弃一个或多个子带（LL、LH、HL 和 HH）来执行压缩。输入源图像，并显示输出图像并确定其 PSNR。与源图像相比，您对输出图像的质量和数据大小有何结论？

6. 进阶成果

 通过对每个子带的抽取器输出端的数据应用重新量化来执行压缩，而不是完全删除整个通道。确定压缩图像数据的数据大小，以及 PSNR 的保真度。描述压缩图像与原始图像相比的质量。

 开发一个用户友好的图形用户界面，用于分别加载和保存源图像和压缩图像，以及控制各种功能（例如压缩、重新量化每个波段等），并显示重要结果。

**3. How is compression attained?**

Subband filters are usually employed in compression. The compression side (a.k.a. encoder) decomposes the input signal into two or more channels and the output of each channel is re-quantized or removed, and then stored or transmitted.

Consider the 2 channel multi-bank filter in Figure 1. Suppose there are *N* input samples in each represented by *q* bits per sample (bps). The input bit-rate is *Nq* bits. For each channel, the output of the decimator is *Nq*/2 bits. Since there are 2 channels, the total bit-rate after the encoder is still *Nq* bits. In another words, there is no reduction in data. Compression can be achieved by re-quantizing the data ( and ) with fewer bits between the decimators and interpolators, or simply removing one of the channels.

1. **Simplistic type of compression**

A simple compression will be to remove the channel with less information on the signal. For data like images and audio signals, the information is often concentration at the low frequency end, and sparse at the higher frequency band. Hence removing the high frequency band results in compression without causing severe distortion. However, the fidelity of the compressed signal is not as good as re-quantizing the data after the decimators.

In the given PR structure, channel 1 and 2 correspond to a low-pass filter channel and a high-pass filter channel, respectively.

The simplistic type of compression is to preserve channel 1 alone, i.e. the low frequency band of the input signal.

**5. Basic outcome**

1. Based on the one-dimensional (1-D), 2 channel PR filter in Figure 1, implement with Matlab a two-dimensional (2-D) PR filter for processing digital images (refer to notes “SIG4.pptx”.
2. You are given two 2-D test images for testing, which you can download in Canvas under the module “Miniproject 2”.
3. Input a source image to the 2-D PR filter implemented in 5(a). Show the image at the output image of the filter and determine its fidelity in peak-signal-to-noise ratio (PSNR) with unit of decibel (dB). What can you conclude on the quality and data-size of the output image as compared with the source image?

Please refer to Appendix A on the use of PSNR in comparing a pair of images.

1. Perform compression by discarding one or more of the sub-bands (LL, LH, HL, and HH). Input a source image, and display the output image and determine its PSNR. What can you conclude on the quality and data-size of the output image as compared with the source image?

**6. Advanced outcome**

* Perform compression by applying re-quantization to the data at the output of the decimator for each sub-band, instead of completely removing the entire channel. Determine the data size of the compressed image data, and the fidelity in PSNR. Describe the quality of the compressed image(s) as compared with the original one.
* Develop a user friendly GUI for loading and saving the source and the compressed images, respectively, and for controlling various functions (e.g. compressed, re-quantizing each band, etc.), and showing important results.

**Appendix A – Peak Signal to Noise Ratio (*PSNR*)**

*PSNR* is a method to measure the difference between 2 images of identical size. The higher the value of *PSNR*, the lower is the difference. The distortion results in compression can be determined by computing the *PSNR* between the source image, and the image that had been compressed.

Given a source image  and an compressed (encoded) image  with horizontal and vertical resolutions of *M* by *N* (i.e., *M* rows and *N* columns), the difference between them can be reflected by the Mean Square Error (*MSE*) as:

附录 A – 峰值信噪比 (PSNR)

PSNR 是一种测量相同大小的 2 个图像之间差异的方法。 PSNR 的值越高，差异越小。 压缩中的失真结果可以通过计算源图像和已压缩图像之间的 PSNR 来确定。

给定一个源图像和一个水平和垂直分辨率为 M × N（即 M 行 N 列）的压缩（编码）图像，它们之间的差异可以通过均方误差 (MSE) 反映为：

 (5)

The Peak Signal to Noise Ratio (*PSNR*) is defined as:

 dB (6)

where *q* is the number of bits used in representing the pixel value of . For an eight-bit representation (i.e. the dynamic range of each pixel is quantized into 256 levels), the *PSNR* becomes:

其中 q 是用于表示 的像素值的位数。 对于 8 位表示（即每个像素的动态范围被量化为 256 个级别），PSNR 变为：

 dB

The *PSNR* reflects the distortion on the encoded image  as compare with the source image .

PSNR 反映了编码图像与源图像相比的失真。

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1. 输入图像得到亮度矩
2. 对亮度矩阵Z变换得到数字频域图
3. 用频域图乘以pr滤波器得到滤波后的亮度矩阵（滤波器也要是个矩阵）

如何知道高通滤波器的矩阵形式？

1. 再对矩阵抽样M=2
2. 再进行插值
3. 对矩阵进行Z变换得到数字频域图
4. 再乘以PR滤波器得到滤波后的亮度矩阵
5. 把两个通道的亮度矩阵相加，这就是重建
6. 把矩阵变换为图像

I=mat2gray(x);%将数值矩阵X转换为灰度图像 读出来的才是一个数组，彩色的话是3个