行政院國家科學委員會專題研究計畫　期中進度報告

子計畫三:應用於音視訊及多媒體信號處理的副頻帶濾波器組之設計(2/3)

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計畫主持人：李枝宏

計畫參與人員：楊元豪，林煜偉，常肇元，許振球

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行政院國家科學委員會補助專題研究計畫期中成果報告

應用於音視訊及多媒體信號處理的副頻帶濾波器組之設計**(2/3)**

Design of Subband Filter Banks for Applications in Audio, Video, and Multimedia Signal Processing (2/3)

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共同主持人：
計畫參與研究生：楊元豪, 林煜偉, 常肇元, 許振球.

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主持人：李枝宏　　國立臺灣大學電機工程學系教授

計畫參與研究生：　楊元豪，林煜偉，常肇元，許振球

一、中文摘要

本計劃已完成預期之研究工作一基於 L_1 與 L_2 最佳化準則的 FIR 具有線性相位且低相位延遲之鏡像對稱副頻帶濾波器組之理論與設計，基於最小絕對值重建誤差與最小平方 FIR 濾波器止帶響應之設計理論，在本項研究內，我們研發基於 L_1 與 L_2 最佳化理論設計以 FIR 濾波器為架構具有線性相位且低相位延遲之鏡像對稱之副頻帶濾波器組理論與設計技術。在理論上，研究推導 FIR 具有線性相位且低相位延遲之鏡像對稱之副頻帶濾波器組的系統架構模型。然後，研發設計此副頻帶濾波器組的最佳化技術。電腦模擬實驗已驗證本計畫成果之有效性。

關鍵詞：有限脈衝響應濾波器、副頻帶數位濾波器組。

二、英文摘要

This project has accomplished research work for the development of the theory and system structure of FIR quadrature mirror filter (QMF) banks with linear phase and low group delay response. Utilizing an approximation scheme and an iterative algorithm, we have developed a method to design a two-channel QMF bank with continuous coefficients in the sense of absolute value of reconstruction error and least-squares stopband response criteria for analysis filters. It is shown that the optimal filter coefficients can be obtained by solving only linear equations. In conjunction with an iterative algorithm, a method is then presented to obtain the desired design result. The effectiveness of the proposed design technique is demonstrated by several simulation examples.

Keywords: FIR Filters, Subband Filter Banks。

三、緣由與目的

Due to the fact that multimedia information becomes a necessary part of modern life, processing the audio or video signals of multimedia information has been viewed as an important research work. To deal with the difficulty of large data capacity required for transmitting multimedia signals, one of the possible remedies is to develop advanced digital signal processing technology for reducing the required information regarding the audio and video signals. In other words, the techniques of bandwidth compression and decompression, coding and decoding should be considered. Using subband filter banks has been recognized as an efficient approach for achieving the above purposes. Most of conventional design techniques consider the design of quadrature mirror filter (QMF) banks using finite impulse response (FIR) filters with some kind of symmetry in filter coefficients to keep the linear phase response. However, the system delay of the designed QMF bank is determined by the lengths of the FIR filters used; hence, the long overall system delay of a QMF bank with linear-phase FIR analysis filters may prohibit practical applications for processing multimedia signals. Therefore, it is worth investigating the design of FIR QMF banks with low group delay. In this three-year research project, we will focus on the development of design theory for subband filter bank with low group delay. Based on several useful optimization criteria, we will develop efficient techniques for designing the subband filter banks to achieve the goals of minimizing magnitude and group delay errors for processing audio and video signals of multimedia data

四、研究方法

First, the QMF banks with a low group delay response for realization is developed。Then, a method is developed based on an approximation scheme for designing a continuous-coefficient QMF bank with optimal reconstruction response and stopband response for its linear-phase (LP) FIR analysis and synthesis filters in the absolute value (L_1) and the least-squares (L_2) sense. This method is further incorporated with an iterative algorithm to optimally design QMF banks with L_1 reconstruction response and L_2 stopband response for analysis and synthesis filters. It has been shown that the design method can achieve satisfactory design results.

五、研究成果與討論

Here, we present simulation results of designing two-channel FIR QMF banks for illustration and comparison. To perform the design process using the proposed technique for all design examples, the spacing for two adjacent frequency points in $[0, \pi]$ is set to $\pi/299$. i.e., the number of grid points taken in $[0, \pi]$ is 300. The performance for the designed QMF bank is evaluated in terms of the peak stopband ripple (PSR) in dB, the maximum variation of passband group delay (MVPGD) of the analysis filter in samples, peak reconstruction error (PRE) in dB, the maximum variation of the group delay (MVGD) the designed QMF bank in samples, and the maximum variation of the QMF bank response (MVFBR). They are defined as follows:

PRE = $\max\{\ |20\ \log_{10}|\ T(\omega_l)\ \|\ \}$(dB), for $\omega_l \in [0, \pi/2]$

$$\text{PSR} = -20\log_{10}\left(\max_{\omega_l \in [\omega_s, \pi]} \left|H_0(e^{j\omega_l})\right|\right) \ (\text{dB}),$$

$$\text{MVPGD} = \max_{\omega_i \in [0, \omega_p]} \left|GD\{H_0(\omega_l)\} - g_d/2\right| \ (\text{samples}),$$

$$\text{MVGD} = \max_{\omega_{l \in [0, \pi/2]}} \left|GD\{T(\omega_l)\} - g_d\right| \ (\text{samples}),$$

$$\text{MVFBR} = \max_{\omega_{l \in [0, \pi/2]}} \left|T(\omega_l) - e^{-jgd\omega l}\right| \ (\text{dB}),$$

where $T(\omega_l)$ denotes the frequency response of the designed QMF bank, $H_0(\omega_l)$ the frequency response of the designed analysis lowpsss filter, $GD\{\text{x}\}$ the group delay of x, and ω_p the passband edge frequency of the analysis lowpass filter $H_0(\omega_l)$.

For the first design example, the order and the stopband cutoff frequency ω_s of the required analysis filter are 24 and 0.6π, respectively. Moreover, the group delay of the QMF bank is 11. For the second design example, the order and the stopband cutoff frequency ω_s of the required analysis filter are 29 and 0.6π, respectively. Moreover, the group delay of the QMF bank is 19. For comparison, the design results of using the technique of [17] to design the same example based on the least-squares criteria (L_2) are also presented. Table 1 lists the significant design results for the first example, while Table 2 shows the significant design results for the second example. From the presented design results, we note that the developed technique provides more satisfactory performance as compared to the technique of [17].

In this project, we have developed a technique for the optimal design of two-channel QMF banks with linear-phase FIR filters and low group delay response. First, we formulate the design problem with continuous coefficients for the optimal criteria, namely, the absolute reconstruction response and the least-squares filter stopband response. An approximation scheme has been utilized to achieve the design of optimal response behavior. In conjunction with an iterative algorithm, an efficient method to obtain an optimal design with low group delay response has been presented. The effectiveness of the proposed technique has been demonstrated by several design examples.

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***Table 1**: Significant design results for Example 1*

	Proposed Technique	Technique of [17]
Filter orders	24	25
No. of filter coefficients	25	26
PSR (dB)	22.1782	22.05
MVPGD	0.0634	0.1679
PRE (dB)	0.0972	0.1359
MVGD	0.2260	0.3513
MVFBR	1.12×10^{-2}	1.59×10^{-2}

***Table 2**: Significant design results for Example 2*

	Proposed Technique	Technique of [17]
Filter orders	29	29
No. of filter coefficients	30	30
PSR (dB)	31.3075	30.30
MVPGD	0.0227	0.0459
PRE (dB)	0.0228	0.0405
MVGD	0.0584	0.1176
MVFBR	3.0×10^{-3}	4.9×10^{-3}