# Project: Summarizing and Analyzing Research Papers

## Submission Template

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**Topic**: Engineering

**Research Paper**: Heliyon 10 (2024) e3191 , Designing optimal prototype filters

### Initial Prompt (How can i connect many filters together?)

**Description (50 words max)**: In this research paper we are going to design optimal prototype filter banks. But initially we have to know that how can we connect filters together.

**Generated Summary (100 words max):** To connect multiple filters together, you can use several techniques depending on the application and the structure of the filter bank. Below are common methods to combine filters:

### 1. ****Cascade (Series) Connection****

In this method, the output of one filter is fed as the input to the next filter. This approach is useful when you want each filter to progressively refine or adjust a signal. The overall transfer function Htotal(z) of cascaded filters is the product of the individual transfer functions

H1(z),H2(z),…,Hn(z):

Htotal(z)=H1(z)⋅H2(z)⋅⋯⋅Hn(z)

This is commonly used in **multistage filtering**, where each filter might focus on a specific frequency band (e.g., a low-pass filter followed by a high-pass filter).

### 2. ****Parallel Connection (Filter Bank)****

In a parallel connection, different filters operate on the same input signal simultaneously, each processing different frequency bands (e.g., sub-band coding). The outputs of all the filters are combined together. This is typically used in **filter banks**. The overall transfer function is the sum of the individual filters:

Htotal(z)=H1(z)+H2(z)+⋯+Hn(z)

This is useful for **sub-band coding**, audio processing, or multirate systems, where the signal is divided into different frequency components, processed, and then reconstructed.

### 3. ****Multirate Filter Banks****

In a multirate filter bank, each filter operates at a different sampling rate. This involves **decimation** (down-sampling) after analysis filters and **interpolation** (up-sampling) before synthesis filters. The key steps include:

* **Analysis filter bank**: Splits the signal into multiple frequency bands using filters, each followed by decimation.
* **Synthesis filter bank**: Recombines the signals by interpolating and filtering.

This approach is used in **cosine modulated filter banks (CMFB)**, as discussed in your paper. Filters are designed to ensure minimal distortion and aliasing during the reconstruction process.

### 4. ****Feedback Connection****

In more complex systems, you might use feedback connections, where the output of a filter is fed back to the input, often in combination with other filters. This is typical in **adaptive filtering** and **recursive filtering** systems.

### Iteration 1( In M-channel filter bank ,significance of “M” )

**Description (50 words max)**: In initial prompt we saw how can we connect filters to make filter bank. With the help of this filter bank we want maximally decimated .but before this we have to know about meaning of “M”.

**Generated Summary (100 words max)**: A filter bank serves as a system that divides an input signal into multiple frequency bands through filters. An analysis filter bank divides a signal into frequency components, while a synthesis filter bank rebuilds the original signal from these extracted components."Maximally decimated" means that the filter bank has the highest possible level of downsampling or decimation, where the output signals at each band are highly reduced in sampling rate compared to the input signal. This downsampling is typically by a factor of M, hence the term "M-band".

The roll-off factor influences the shape of the individual filters in the bank. It can affect properties such as the reconstruction quality, filter selectivity, and overall performance of the filter bank. A higher roll-off factor typically results in steeper transition bands and better stop band attenuation but may also increase computational complexity. Conversely, a lower roll-off factor results in gentler transition bands and potentially lower computational requirements but may sacrifice stop band attenuation and selectivity.

### Iteration 2 ( What is cosine modulation? )

**Description (50 words max)**: After filter bank and M- channel designing our next step is cosine modulation. so now in second iteration we should know about cosine modulation.

**Generated Summary (100 words max)**: Cosine modulation is a technique used to design filter banks, particularly in **Cosine Modulated Filter Banks (CMFB).** It involves modulating a low-pass prototype filter with cosine functions to generate a set of band-pass filters. These filters can divide the input signal into multiple sub-bands, making it useful for applications like **sub-band coding, signal compression**, and **multirate signal processing.** In CMFB, the key concept is that all analysis and synthesis filters are cosine-modulated versions of a single prototype low-pass filter. This reduces the complexity of designing multiple filters, as the filter bank design is based on a single filter with cosine modulation applied across different frequency bands.

### Final Prompt (Is cosine modulated filter bank differ from prototype filter bank?)

**Description (50 words max)**: Finally we designed cosine modulated filter bank which is outcome from prototype filter banks. here we want main differences in between them.

**Generated Summary (100 words max)**: Cosine Modulated Filter Banks (CMFB) are a type of filter bank structure where multiple filters are designed by modulating a single low-pass prototype filter with cosine functions. CMFBs are extensively used in **multirate signal processing, sub-band coding, data compression**, and **digital communications**. All filters in the bank are cosine-modulated versions of a single low-pass prototype filter. This allows the design of M-band filter banks (where M is the number of sub-bands) by simply shifting the frequency response of the prototype filter. CMFBs often operate with maximal decimation, meaning that the number of output samples is minimized while avoiding aliasing, which makes them computationally efficient. CMFBs are designed to reconstruct the original signal with minimal distortion. They achieve NPR by carefully optimizing the prototype filter to minimize amplitude, phase, and aliasing errors across the sub-bands.

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### Insights and Applications

**Key Insights (150 words max)**: Cosine Modulated Filter Banks (CMFB), M-channel Filter Banks, Near Perfect Reconstruction (NPR), Perfect Reconstruction (PR), **audio compression**, **sub-band coding**, and **ECG signal processing, high-fidelity**, high-precision filtering, Computational Load.

**Potential Applications (150 words max)**: Audio and Video Compression (e.g., MPEG, MP3), Sub-band Coding, Medical Signal Processing (ECG, EEG), Digital Communication Systems, Multirate Signal Processing, Speech Processing and Enhancement, Radar and Sonar Systems, Image Processing and Compression, Hearing Aids and Audio Devices, Telecommunications (Adaptive Filtering), Data Transmission in IoT and Wireless Sensor Networks, Cognitive Radio and Spectrum Sensing.

### Evaluation

**Clarity (50 words max)**: This paper proposes an optimized design method for Cosine Modulated Filter Banks (CMFB) using a single low-pass prototype filter. It ensures rapid convergence and minimizes amplitude and aliasing distortion, making it highly efficient for applications in audio compression, signal processing, communications, and medical diagnostics.

**Accuracy (50 words max)**: This paper has published in reputed journals with authentication .all methods, formula and graphs were very clear and prospective.

**Relevance (50 words max)**: This topic designing of optimal prototype filters are very common and unique concept which is discussed in paper. This subject is mandatory in all engineering branches.

### Reflection

**(250 words max)**: Through this assignments and course really i feel confident regarding Artificial intelligence. In present scenario artificial intelligence, cyber security, data mining, machine learning etc are daily life facing situation. These all are covered by all branches in engineering as well as other fields also. Particularly in assignments really i have many problems such as firstly understanding the concept and visualization. because of a good journal paper you cant understand the problem without many times reading. But i read three to four times and pick prompt .

Apart from that when i read three to four times research paper really learn mostly about filter banks and many new terminology which was used in paper. Without learn this all terminology you cant imagine whole concept. Just example – in this paper new term was cosine modulator. first time i was shocked about hear this term because of i knew about modulator but dont know about cosine modulator. Similarly many words has came which was shocked for me. But overall through all activity i learn most of things especially artificial intelligence.

So thanks .