LAB # 5

NAME:______________ ___ **ROLL NO:_________________**

Aim:

Aim of todays' lab is understand the importance of frequency domain, its transformation from and to time domain and implement an algorithm which makes use of frequency domain knowledge.

Theory and Task:

The human listening system determines the rhythm of music by detecting a pseudo-periodical succession of beats. The signal which is intercepted by the ear contains a certain energy, this energy is converted into an electrical signal which the brain interprets. Obviously, the more energy the sound transports, the louder the sound will seem. But a sound will be heard as a beat only if his energy is largely superior to the sound's energy history. That is to say if the brain detects a brutal variation in sound energy. Therefore if the ear intercepts a monotonous sound with sometimes big energy peaks it will detect beats, however, if you play a continuous loud sound you will not perceive any beats. Thus, the beats are big variations of sound energy. This brings us to our task for this lab.

We will design a frequency spectral analysis based algorithm that can identify beats in the signal (at different times). This will be done using spectral energy analysis in bin of frequency instead of complete frequency band. Once the beats are identified we are required to

a. Provide total number of beats identified in a specific sub-band of frequency
b. Provide the sub-bands that are identified consecutively.
c. Provide the sub0band that contains the beat for each frame of the signal (i.e. at different time intervals)
d. Provide the sub-band, for each time interval, where the beat has maximum energy.

General Concept of the algorithm is as follows:

We will be running algorithm on the frames of 1024 new samples from signal in each iteration, and pass them to the frequency domain using FFT. We will than obtain 1024 frequency spectrum. We then divide this spectrum into however many subands we like, here we will take **32**. The more subands you add more sensitive your algorithm will be but harder it will become to adapt it to lots of different kinds of songs. Finally, we compute the **sound energy** contained **in each of the frequency subands** and we compare it **to the recent energy average corresponding to this frequency band (average energy of past 43 frames)**. If one or more subbands have energy superior to their average we have detected a beat.

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Pseudo Code for identification of beats in a signal:

Time domain signal is first divided into frames of 1024 sample each. For every frame of 1024 samples

- Compute FFT on 1024 sample taken in $\boldsymbol{an}$ and $\boldsymbol{bn}$ (Stereo sound).The FFT inputs a complex numeric signal. We will say $\boldsymbol{an}$ is the real and $\boldsymbol{bn}$ is the imagery part of the signal. Thus the FFT will be made on **1024** complex values of:
$$an + 1i * bn$$
- From FFT we will obtain **1024** complex numbers. We will compute the square of these modules and store it into a new Buffer. This Buffer B contains the **1024** frequency amplitudes of our signal.
- Divide the Buffer into **32** subbands, compute the energy of each of these subbands and store it as Es. Thus Es will be **32** size and Es(i) will contain energy of subband 'i'.
$$Es(i) = \frac{32}{1024} \times \sum_{k=i*32}^{(i+1)*32} \mathrm{B(k)}$$
- Now to each subband 'i' corresponds an energy history buffer called Ei. This buffer contains the last **43** energy computation for the 'i' subband. We compute the average energy <Ei> for the 'i' subband using:
$$< Ei >= \frac{\mathbf{1}}{\mathbf{43}} \times \sum_{k=1}^{\mathbf{43}} Ei(k)$$
- Shift the sound energy history buffers E_i of 1 index to the right. We make room for the new energy value of subband 'i' and flush the oldest.
- Pile in the new energy value of subband 'i': Es(i) at Ei(1)
$$Ei(0) = Es(i)$$
- For each band if $Es(i) > (C *< Ei >)$, we have a beat!