Lec 07 - Basics of BCI and Signal Processing

Hello everyone, welcome to the course Microsensor, Implantable Devices and Rodent Surgeries for Biomedical Application. I am Ratin Joshi, I will be mostly discussing about the neural signal processing aspects and some of the applications. I am a PhD student here at BEES Lab DESE IISc and in today's class we will be looking at as I mentioned some of the applications, how to realize that application, how to process the signal for that particular application. So you know we already, this course would be conducted by Dr. Hardik Pandya and Dr. Shabir Girishan who is a neurosurgeon.

So some of the aspect which has been already covered in theory I would be providing a little bit on MATLAB simulation and some of the signal computational approaches, how to work of course not for all application it is not possible to explain each and everything. But we will try to give the gist of the processing or you know the computation what we do that will help you to decide the flow for that. So before going through each and every problem I will just quickly show you some of the applications, some of the problems and what is the context. Always you know signal processing without knowing a context or processing any biomedical data without context, without knowing experimental protocol will not you know lead to some of the conclusive inferences which will be helpful.

So considering this fact we will just quickly see that how things have been done, what are the signal, how they have taken, at which anatomical level it has taken. Mainly as I mentioned I will be discussing about the neural aspect, so I would be talking about EEG, ECOGS, SEG, what are all these things we will quickly see that in today's lecture and then how it is useful to further you know make devices, sensors and overall systems and all. So if you can see my screen here there are different modalities at which your biopotentials are taken is shown. Here you see EEG is the first one which is recorded from the scalp and which is a non-invasive technique and that is why it is the primary method to take any for any neurological disorder. If you go to a doctor or neurologist or neurophysiologist, epileptologist etc. the first thing would be get your EEG done, why because it is a non-invasive, you do not need to perform any surgery for that, there would not be any risk of tissue damage infection and all. However, for some of the scenarios or some of the conditions you have to do the surgery and go deep in your head or skull, so then you will take ECOGS which are like taken from the cortex or skull. Here you see this is like a nice illustration where is scalp, so this brown colour region is the scalp whereas this is your skull, this is dura, this is pia, this is grey matter, this is white matter. Now what is this grey matter, what is white matter, how it looks like, everything we will see when we perform surgery. Now it is like as you already know that for neurological resource as Prof. Hardik mentioned this is the flow for neurological research right to prove or any you know put any new things into the prospective as brain is very very

sensitive organ and comparatively less explored there is a flow for research. First you start with rat, then cats, monkeys which is also known as non-human primates and then you go to the humans, so this is the flow. So we will be showing you in this particular subject rodents neurosurgery as the name of the topic and we will see how the all these anatomical region looks like in that particular surgery and also there is a strategic reasoning or rational behind going at which level like if EEG itself is enough we do not have to do any kind of surgery, we do not have to go subdural or intradural or we have to for some of the things we even go to the depth which is like in the white matter right. So that is there are some problems, there are some conditions known as Parkinson's or something for which you have to stimulate your brain using some current. Also there are some other memory loss and all there are research going on that basically in a layman term in a simpler term it will rewire or it will restructure your brain network so that you can get your you know proper connections or network electrical network of the brain going.

So it is all about you know synchronous neuronal activity like as you see for epilepsy also if there are neurons which gets fired in a synchronous fashion and in an uneven way then it will happen that you will be getting an epileptic seizure right. So it is all about how your neurons and there are different types of you know cells available pyramidal cells and some cells will inhibit the activity of that and proper balance is required for a proper you know brain functionality to work. So considering that we will decide that which modality to do, how deeper we should go based on your condition, problem and also these all are bio potential what I have mentioned. It is like mostly you will get a one-dimensional temporal traces. Also you can perform some of the imaging technique right MRI, fMRI or spectroscopy technique and all.

So MRI technique or modality has its own pros and cons and conveys a significant amount of information. This is a very nice summary of the BCI techniques which has been used. How better you can go in terms of temporal resolution and spatial resolution that is always a trade-off. So if you can see here this looks the best right the ECOG or SEG which has a very less temporal resolution. What do you mean by temporal resolution? The moment something you know you do some particular task your brain reacts to that that can be captured in your brain waves.

I mean a very simplistic term suppose like we are taking a normal EEG from your forehead. Now this is called forehead which region of the head what it is called what is nomenclature will be covered by Professor Pandya that is like 10-20 system and all that is a prefrontal, frontal, central, parietal, then temporal and occipital and all. So for particular experiment you should know where to put the electrode. A very simplistic example I am giving for now is if you are recording your EEG from here first of all to

record any bio potential you require 3 electrodes ok. One is just a second yah one is active electrode ok. Second one is reference electrode and third one would be ground. Now why this 3 electrode?

This 3 electrode will be inputted or given as an input to your acquisition system and this is true for any bio potential not only EEG. The same is true for ECG you all know right what is ECG? Like EEG corresponds or give you information about brain state of the brain right ECG corresponds to heart right. Some of the movies or somewhere you would have seen there will be variation suddenly it goes flat line so that heart stops working. Similarly there is something called EOG electro oculograph used for eye tracking and similar application.

Also there is something called EMG electromyography. When you have moment disorder or something like that your muscle movement right. So as I am just giving you an analogy this is eye this is muscle. So this is organ this is bio potential. All these things recorded using active reference and ground this 3 electrode which is decided by acquisition system it is nothing but electronics module.

In this course only one of my colleague would be explaining how to design electronic module and all this thing. So then electronic module what it will have finally the things whatever used here to capture the data. Data is our bio potential which is a continuous or I should say analogous quantity but we are doing all the processing or signal processing what we will be explaining would be in terms of numbers digits right in your system. So then sampling and all will be done but the heart of the acquisition remains ADC. And if we I will not go into too much of detail of electronics but in that there will be instrumentation amplifier okay.

So there are several things what is sampling rate what is resolution and all based on your application you can decide all this thing. So yeah coming back to like this is just a brief overview of the things what electronic module or how many electrodes are used and all. So I was explaining about temporal resolution and for that I was telling that we will put the electrode on the forehead here and let us say this is just a trace I asked subject to blink at this particular moment and then this is a normal thing. Then if you can see me that electrode would be placed on my forehead which is yeah if you can see me if one electrode is placed here which is on your forehead right here and you can use your ear lobes or mastoid as a reference and ground. So like that if you can put your three electrode active on forehead okay reference and ground on ear lobe okay.

So if you can keep like this okay then and you are recording EEG let us say this is some baseline and the moment you blink you will get this kind of pattern known pattern okay. So the moment you blink here and the moment the pattern came that is nothing but your

temporal resolution okay. So that is what temporal resolution is all about you know how fast your device can react based on your action or how fast your device can capture the moment of your brain waves based on a particular action. So further there is a spatial resolution right finally the data or you know biopotential comes out of the head but where the action happens let us say you are taking EEG from this particular location right but there will be some neurons here which is contributing to this location there will be some neurons here which is contribution to this location there will be some neurons here contribution to here right but and on a different intensity. So how to identify the data which is obtained from here it has how spatially the data has come so that can be identified if you have a proper spatial resolution.

So if you can see now in this particular graph here EEG is there but has a poor spatial resolution excellent temporal resolution EEG a poor spatial resolution excellent temporal resolution where you go ECOG or SEG which is taken in the deeper region of brain you will still get a same temporal resolution but your spatial resolution is also good then it is the very good thing right why should we take EEG. SEG or ECOG gives a really good result with a great excellent spatial resolution and temporal resolution. However that comes if you see the color of the dot EEG is completely white whereas the SEG or ECOG is black which shows the invasivity. So then the data is recorded from your brain which means brain surgery is performed which comes with his own pros and cons. So there is a trade-off you have to decide that which modality you want to record and how you want to proceed.

Of course there is a near infrared spectroscopy functional MRI PET scan and all different imaging techniques are there so you can explore it by yourself but considering there are multiple parameters as I said here just three are considered spatial resolution, temporal resolution, invasivity. Much more parameters and much more condition-specific parameters are there. So based on that condition specific as such if epilepsy is there you should go for one particular modality if brain stimulation is there you should go for one particular modality if Alzheimer is there, anxiety is there, depression is there there are several neurological disorder based on that you have to decide. So it is a subjective measure or subjective way of treatment which needs to be identified and for which neurophysiologists, doctors and everyone comes to the picture. So what are the applications and all? So what we can solve if we can you know we do the signal processing with a little bit of you know knowledge of mathematics and fundamentals of mathematics.

So I will just show it to you the applications here. What are the basic applications which we will be looking at to solve in this particular course. So first thing is epilepsy. So epilepsy screening we will see how we can automate the data which is obtained using

your entire head and we will also identify where is the origin right very important in your head or you know where the uneven activity starts, how it progresses based on that there are different you know types of epilepsy. There is something called focal epilepsy, where focus is identified something called generalized epilepsy.

This all things would be covered by Professor Hardik in his course. So I am just going little bit fast where additionally there is something called drug efficacy right. You have epilepsy, you are taking anti-epileptic drug which anti-epileptic drug is bad good for you or bad for you. So screening of anti-epileptic drugs. How do you identify that? Let us say you are currently you are in a normal state or you are having an epilepsy okay.

This is a normal state, this is epileptic state okay. Then AED is given anti-epileptic drugs and now again you came back to this normal state. This was normal 1, this is normal 2. AED 1 was given. Let us say AED 2 is given okay and you have come back to another normal state.

Now this is also normal. Now what do you mean by normal state? When you record the data, it will not give you any uneven or unintended temporal traces of EEG or ECOG or SEG right. There would not be any uneven disturbances of electrical networks and all this thing. So this is also a normal state, this is also a normal state. Let us say this baseline has a value of 50 microvolt. This generally EEG is recorded or measured in microvolts.

Whereas this is also baseline got restored after AED, it is having 30 microvolt. Whereas here it is around 80 microvolt. Now this is also a baseline, a normal EEG, this is also a normal EEG, which one of them is better right. So that you can identify by recording and processing the signal to know that okay this baseline is this, this is this. But however in this particular value also there are some discharges which can you know which is progressing towards the epileptic waveform or epileptic pattern.

So to know the pattern, quantify the pattern, which channel it is coming and all. So all this you have to perform an analysis that is known as a spatio-temporal analysis and all. At some point of time I will share the paper with you. So you can identify. First we will just go through the entire process, then I will share the paper with you, so you can identify.

Further one very important thing is sleep. Now for your system or computer, laptop to work, you have to turn it off or you should have log off or restart it right at one particular point of time. Same goes for our body. All humans at any particular age need at least 6 to 7 hours of sleep to get going and everyone should. So how and sometimes it feels that

even if you slept for 4-5 hours, you feel that wow I had a great sleep and now I am ready for any kind of work.

Whereas in some particular point of time it happens that even after you have slept for 8-9 hours, you feel like disturbed, dizzy, tired and all. So how to identify that? So there is a science for that. There are sleep studies and sleep labs available where regular studies on sleep with different intervention happen that at which particular luminance or light a person should sleep, under which particular sound a person should sleep. Usually when we sleep, we do not prefer any sound. But if a sound or auditory stimulus in a neurological term provided which is in sync with your brain waves, then you will get a better feeling or you know better kind of experience of the sleep.

So in some of the airports, in snoozing zone and all if you go, there will be some water drop or similar sound would be played. That is to give you a better experience because you might not get complete sleep but in limited period of time, you should not feel completely tired or something. So there is a science for that, that can be done, sleep quality assessment and improvement. So insomnia and all, sleeping disorder, something called sleep apnea as well. You can identify the sleep quality using not only EEG but also snoring sound which is sometimes you might feel that snoring is annoying but when you combine it, snoring sound with EEG, you can get a very significant information about your sleep quality.

So that is also important. Also fatigue detection, I will be keep on speaking in this particular class and what if you get bored. So whether you actually get bored or when should we take a break, not only this class. If I talk about, if you are working in one particular company, there is something called Pomodoro technique, Japanese technique. You work for 25 minutes and take 5 minutes break, after 4 break or you take one big break. So do we really have to follow or is it subject specific? So my experience is if I work on one particular thing which I like, then I can work for 3, 4, 5 hours also.

It depends on person to person. So whether, when you are actually fatigue, when should you take a break? This will be used in any of the multinational companies for productivity management. This all can be done by just wearing a small helmet or small headband or headband, just a normal band like you used to wear and it will say okay now you can take a break, it is possible. Also some other application but so far, this 5 application whatever I have talked so far, these are all application of free running EEG. Now when I say EEG, other parameters can also be there or other modalities can also be measured like as I mentioned for sleep quality and improvements, snoring sound.

So these are free-running EEG. What do I mean by free-running EEG? Free-running

EEG is normal EEG is being recorded without any kind of intervention or without any kind of stimulus. Of course, when you put for improvement, it is a stimulus-based EEG but otherwise it is a normal free-running EEG. When you add EEG plus stimulus, any stimulus, stimulus can be audio, it can be video, it can be any kind of let us say particular fragrance, it has its own importance. So I will come to that or it can be a touch, touch generates somatosensory evoke potential. All this thing EEG plus stimulus will result in evoke potential.

When I am speaking, you are listening, EEG will be speech evoked EEG, you will think something, it will be some other EEG. If you see something and suddenly you see something which is unexpected, there are few potentials or evoke potential will get generated, it is called evoke potential okay. So it is not only evoke potential, if specific to one particular event you are getting your response, it is called ERP, event-related potential okay. First five are the application of free-running EEG more or less. When I say a quality, till quality assessment, it is a free-running EEG whereas the other thing, other related, this brain functionality, coma recovery, all this thing comes under evoke potential or ERP related experimentation.

So this is like free running EEG, then ERP, then some other combinations of both as well. So further it is coma recovery index, when the person is coma, in coma or brain dead right, how much chance is that the person will again come back and resume the normal life, so that can be identified using EEG. So there is a brain functionality assessment in which sensory system assessment, so this if I talk from now, here this is all EP or ERP. Now all of you should know what is EP and ERP, evoke potentials or event related potentials right. So then sensory system, what are the things we will be measuring, mostly it will be hearing screening, cognitive parameters, attention, working memory, all this thing, I will show in the scripting as well using MATLAB, how we can process that and further there are as I mentioned, there are several disorders for neurological assessment which is like Alzheimer, like a kind of memory loss, schizophrenia, you will feel like anger and all, also autism, you will find it difficult to speak, if you know aware in the several cases were there in movies also it has been shown, burfi movie, so that is autism spectrum disorder which is really a challenging condition, also there is ADHD, hyperactivity disorder, depression, current era, thus mental health is a very very concerned topic, so depression is also one of them, so as anxiety.

So all this thing can be identified, detected and once detected it can be quantified as well that whether whatever therapy you have been part of is correct or not, so then neurological disorder assessment is also can be performed, also one good like couple of new thing which is emerging out right, it is gaming EEG, of course again it is a EP or

ERP. Now what do you mean by gaming EEG, I hope most of you are aware about the single-player games and all, if not please search about that, so then gaming EEG where you can use there are something called single player games or action games, person with schizophrenia okay, if you record that how many enemies that person has killed or how hard or with very you know like how forcefully that person has clicked on the button okay, that would be different than a normal person. So again a simple normal game you can make and record EEG simultaneously you will get an inference that whether the person has little bit of you know what is the degree of schizophrenia, how schizophrenic that person is because that has its own, all this Alzheimer's, schizophrenia, ADHD and all has their own consequences right and all are really really important problem, I have only put some of the critical applications which I can easily explain to you, I am not going into the detail of course apart from this if I want to consider and as this course we will be focusing on invasive experiment, we will be looking at DBS also, one of my friend would have already covered few aspects of DBS which is a deep brain stimulation, there are own benefits and you know disadvantages as well to go deeper in the brain and perform the you know surgery or perform the surgery and then provide an electrical stimulation and check how it has resulted or how it has affected your particular brain region and of course all this thing has to be done under a proper ethical approval without that you should not perform any experiment for animals as well. So that is the gaming EEG and furthermore if we move ahead there is something called neuromarketing which is again a niche topic recently I have come across some of the paper on that that in a very simplistic term if I wanted to say you are scrolling through your Amazon or Flipkart websites and one cap has been provided to you which will continuously recording your EEG then by just scrolling through your thing EEG can identify that yeah this person is more likely to buy this item than this other particular item and then all of you know then the era of AI and ML now people even without the EEG currently we are getting exactly appropriate you know appropriate options or recommendations then if we can even merge this kind of modality it will even help. So this is like another application which we will be discussing about and this is like some of the application how do we do that so to identify that particular thing I will show you that what are the applications not every application is possible to cover in this particular course and considering the time factor I would be explaining two three of this and demoing it how to approach and all using which particular modality we will achieve that application I will talk about that also when you see the signal how to see what to see using which mathematical technique we will do that this all like neural signal processing biomedical signal processing even AI ML are the advanced name of mathematics.

So then what techniques will be using of mathematics and further how we will be reaching there using which platform will be reaching there. So this thing I will cover so just a quick summary of what we will be doing in this course we will be checking hearing

screening cognitive metric screening epilepsy seizure classification some of the rodent signal rodent signal means ECOGS, SEG and all taken post neurosurgery from rats and how to draw neural inferences. So like I have come across several situation when we have a data and you know a lot of data rather now because the everyone has started putting the data for making it open access for better analysis but then the lake of you know interpretation ability or you know physiological mapping knowledge they won't be able to come to any particular conclusion. So how to interpret the obtained data and present so that it make neural sense right so that is also again a very important thing we will be looking at that what are the things we will be looking at we will be looking at evoked EEGs, ERPs, free running EEGs, free running ECOGS, SEG as well SEG is nothing but stereo EEG which is like a deep region of your brain very small incision will be made electrodes will be dropped like you know penetrate to your brain and then you will get the recording or you will get the response and like in motor you have a steering right stereo like that it can be placed there and now even with the advancement of robotics and all you can maneuver or navigate your electrodes wherever you want exactly through the area of interest and get this you know information whatever you want to get. So that is again these are the application with the modalities and how do we approach that so some of the basic mathematical aspects I have written here noise removal, filters, synchronization, averaging, averaging is specifically used for ERPs right.

Noise removal is like it is a very important thing to know that what is signal and what is noise it is quantified by signal to-noise ratio you have some signal now alone on noise removal we can talk about hours and hours noise can be of two types one is physiological noise right. I will give you one small example of this also and non-physiological noise physiological noise is nothing but physiological noise is nothing but generated by humans let us say you are taking your EEG from your head or anywhere but it has some footprint which is like repeated 70, 80 times a minute it is highly possible that it can be a cardiac artifact. Now your heart is connected to brain, brain is connected to heart this is one example of physiological noise while going through the recording a person is moving okay for any EEG recording currently we have a lot of advancement in computation however for any EEG recording stable the subject more better the quality of recording that is why it is difficult to get recording from a newborns there is one aspect or one research from our lab works on newborn hearing screening which professor Hardik will cover. So, then you know that there is a physiological type of noise whereas non-physiological type of noise this all EEGs and all are of microvolt range very sensitive and that is why any external intervention non-human intervention can deteriorate it what are they so that can be a line noise as simple as that our power line noise if you are generally the room wherever you are should be electrically having a minimal appliances this is also another aspect of experimental protocol so then it is also

a line noise how do we mitigate that let us say we have a line noise so you should know what is the power line specification right so in India it is around 230 volt 50 hertz when I say 230 volt there will be a fluctuation 220, 230 and all right and 50 also can be 49.9, 50.1 .

How can we remove power line interference? How can we selectively remove that particular component? So for that you have to use filters right filter can be of hardware filter or software filters hardware filter means you have a components it can be active filter or passive filter active filter have active components it will have OPAMP passive filter by only resistors and capacitance right. So that is again a question which it is a trade-off it is a problem of hardware software co-design how do we realize your filter and like some of the acquisition system has their own filters still if there is any noise it is always advisable to remove it using your acquisition parameter using your computational system as well so there are noise removal techniques as I mentioned filtering is one of them which I already discussed and then synchronization averaging pattern recognition which is mainly used for epilepsy screening and finally time frequency analysis for rodent models more or less will be using it I will show you one of the example rodents epilepsy model how this time frequency analysis is being conducted feature extraction very important now this feature extraction and pattern recognition is little bit connected however there is a difference pattern recognition means for as I mentioned for epilepsy professor Hardik also will cover we will be checking something called spike, sharp and wave when I say spike sharp and wave it also consists of combination of that okay, combinations. So that we will check and also classification very important when I say if you see here Caesar classification so which type of Caesar is there why it is important because therapy differs based on types of Caesar so that is also one of the aspect finally we will see the method what we will be using to get this particular applications one is GUI based so there is something called EEG lab I will put the link in the description where I will be explaining how to download EEG lab how to particularly import the data of different format and all which I have covered in one particular course in this course we will see an advanced version of that how to use the EEG lab for several other applications and also this all when I say GUI based processing it is a pre-designed GUI which is for a general purpose GUI okay whereas suppose you I will show it to you in the next class how to use this particular GUI each GUI or each process for one particular application let us say here in screening will require around 40 to 45 clicks and some of the information you have to input using your keyboard right so how is it advisable that if you have 100 subjects data you will do GUI for all 100 subjects it is a time consuming and also prone to human error right so can we automate that so this is our approach number 1 which is GUI general purpose GUI then there is a another approach which is like based on batch file processing batch file processing is very convenient also for remote health monitoring also you have 100 subjects data you just run the script and you know you go out come back all the results are ready just on one click you can forward it

to a clinician or neurologist or any concerned person who can interpret and give the impression of course all this when I say that you have 100 subjects data on one click you transmit and all all follows ethical guidelines the data whatever you got when you any subject human data or any subject data when you transmit it it should be encrypted and decrypted. So there is something called data security protocols and all so that again considering the scope of the course I will not dive too much into detail for that particular aspect but it is doable further there is something called custom app development okay this first point number 1 is general purpose as I mentioned GUI based processing whereas when you have a particular application identified let us say hearing screening. Now hearing screening I want to design an app for hearing screening it has two mode one is for adults okay and second one is for newborn, newborn or neonate now why it is important because when the baby is born baby cannot tell you that yeah I can hear or not yeah there are some behavioral techniques but otherwise it is not possible and if detected on time you can save baby from lifetime disabilities. So this is just a brief context there are two modes adults and newborn what are the parameters you are recording there so we are recording MMN okay what is MMN and mismatch negativity that will be covered by Professor Pandya so I will not go into the detail other thing is ABR. ABR is auditory brainstem response which is a gold standard what do you mean by gold standard this is a technique which is currently in use but MMN gives little bit more information so these two parameters which we are going to record.

So if you have this kind of structure in your mind in your brain that I will be using only this modality of the brain you can develop your custom app when I say hearing screening these are the two parameters when I say cognitive matrix let us say I will be recording something called a tension and working memory right. So when you have your things set when you have your acquisition when you have your data processing pipeline everything set you can go for your custom app development. So in that also there are several types of that first is dependent on one particular format like if you are using MATLAB you can use it a dependent app which requires MATLAB further if you go make a app which is standalone you can use Python or you can use even MATLAB can export finally the standalone app or you can make a web app only with the one particular link you can share that link to the doctor data is taken loaded into that particular web address you can get the results. So again all applications this all applications modalities approach and method all possible combinations are there okay all possible combinations means we can use epilepsy seizure classification let us say using three learning EEG you we have to use in that case noise removal technique filters we have to identify some patterns as well you have to do some time-frequency analysis you have to get that do the classification also and all this thing all this thing can be done using an app using GUI it can be done using scripting it can you can also develop an app which is also three of this. So as I mentioned the lot of combinations are possible and a lot of things can be

discussed but considering the time factor we will be discussing some of the like you know modalities some of the demos and all I will show it to you that yeah so you can see here tentative modules are MMN extraction using EEG lab GUI. MMN as I mentioned mismatch negativity some sound will be presented as you can see here electrodes will be there to take the data sounds will be presented it the EEG will be acquired what sound is presented that also will be given to the signal processing module both the thing will be acquired by signal processing module and then you will get this some pattern okay it is slightly blurry but there will be some patterns for which parameters are known.

Same thing this is for ABR this is for MMN right so this is one of the application which I have shown it here right and this gets generated within 10 millisecond of sound presentation and this gets generated around 150 to 300 millisecond just to give you a context that we if you cannot record within 10 millisecond the signal will go. So it is like electronically challenging to get this kind of signal how do we do and how to process we will see that also as I mentioned MMN and ABR are here also we will show you this MMN we will see using EEG lab GUI as I mentioned I will put the link in the description of how to use EEG lab, download EEG lab and all simple steps then we will directly see how we can extract the data using EEG lab ABR I will show it to you mostly with the customized script okay why I will tell you at that particular point of time. Also, P300 extraction P300 is generally used for attention and working memory okay. So that we will see using a customized app we will also have a look at time-frequency analysis of epilepsy module it will be a very short 10-15 minutes what is just to give you an idea and if time permits we will also see the epileptic seizure classification using a script which is again I am putting it here so what it does is you can see here this is a normal EEG right and then you can see a normal baseline with not much variations whereas during seizure or I should say generalized seizure you can see all the channels are showing this uneven traces. So this how to capture this and compare to this how to quantify the difference between this and this that is nothing but your EEG seizure detection and classification. So based on the time we will try to cover all the modules of signal processing and we will see these are the approaches I will see you in the next module with this demo if you have any questions feel free to write us in the forum as I mentioned I will meet you in the next class thank you bye.