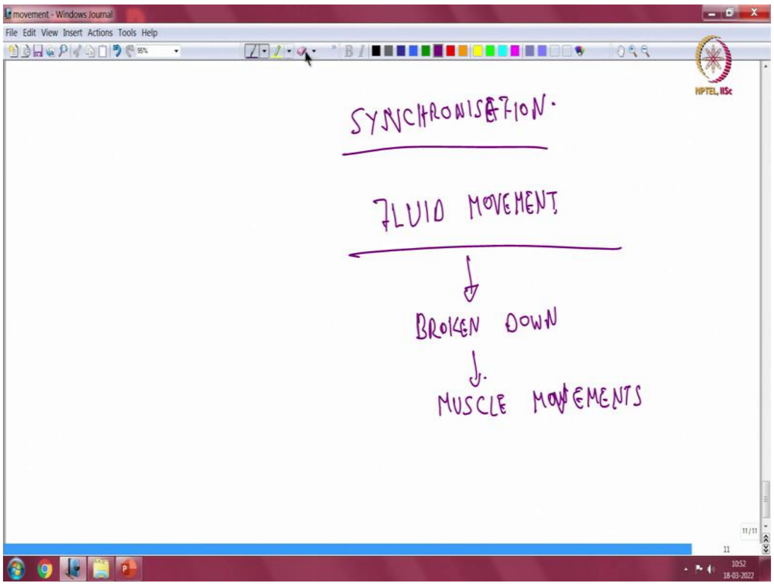
Neural Science for Engineers
Prof. Vikas V
Department of Electronics and Communication Engineering
National Institute of Mental Health and Neurosciences (NIMHANS)
Indian Institute of Science, Bengaluru

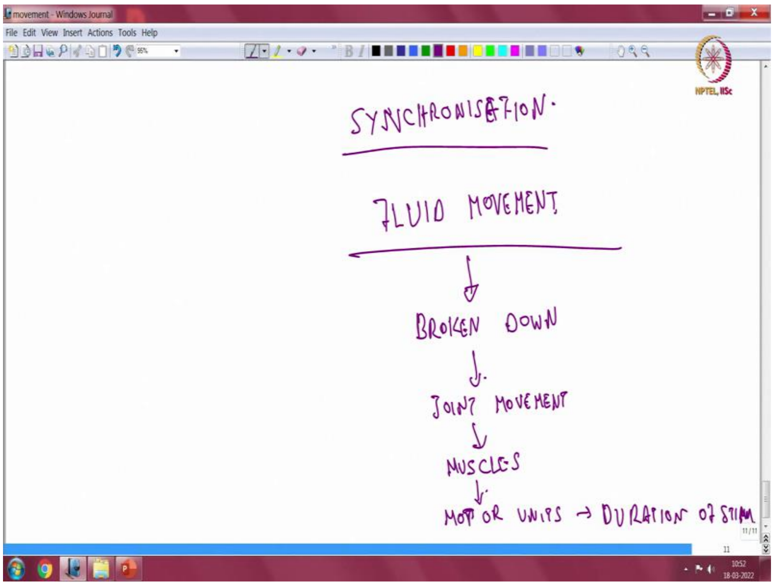
Lecture - 45
Movement: Synchronization

(Refer Slide Time: 00:22)



So, the next activity which I would like to speak about is Synchronisation. So, what do you mean by synchronisation? Synchronisation is how do you ensure that there is fluid movement. So, you know when you pick up an object and it is not a broken down set of movements, it is so fluid that you reach the object and then pick up the object using just about the force which is required to hold the object without crushing it, bending it, allowing it to slip.

(Refer Slide Time: 01:34)



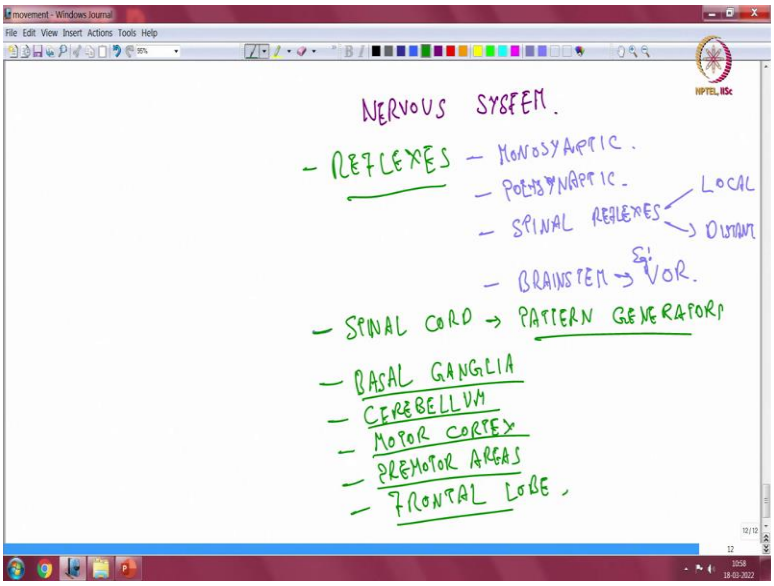
So, all that requires that the fluid movement has to be broken down to individual muscle movements not just muscle movements, I think I am a bit wrong in that you have to first have joint movements then the mapping has to go on to muscles, wherein motor units and duration of stimulation.

So, every movement has to be broken down into this individual thing. So, a movement needs to be split into what joints are to be moved and in what sequence these joints are to be moved. So, it is not one joint after another. So, it is the phase relationships between individual joint movements and the changes that has to be dynamically broken down into that and every joint there are multiple muscles acting on the joint. So, you need to map it into individual muscles.

So, within muscles you have these motor units which I already described. So, based on the kind of activity which is required you need the smaller motor units or the larger motor units, the more powerful motor units are the smaller motor units, which can generate lesser amount of power. And after that you need to also determine the duration of stimulation and the phase relationships between the stimulations, which happen.

So, that sort of gives background as to the challenges which are there within the motor system. So, motor activity and motor activity is a very complex phenomenon. Now, the purpose of giving such a huge introduction on the topic is that there are you know if you look at mechanical actuators you have electromechanical motor you have a signal strength which starts the motor you have a ramp which determines how the motor start functioning and then there is a stop. So, irrespective of that there is just so much of control systems which can be applied on this applied on this formulation.

(Refer Slide Time: 03:44)



If we look at the nervous system, we have multitudes of control system. So, starting with these reflexes I spent a lot of time explaining how reflexes are important. So, you have these monosynaptic, you have polysynaptic then you have spinal reflexes, local and distant. So, local spinal reflexes are within the segment or very close to the segment, distant is across the spinal cord and it can extend into the brainstem also.

So, you have brainstem I spoke about the vestibular ocular reflex example, vestibular ocular when you turn your head the vestibular system activates and then determines how much of eye rotation has to happen to keep fixation. So, that is the vestibular ocular reflexes. Now, over and above these set of reflexes are multitudes. So, these are reflexes, the spinal cord as such has something called as pattern generators, which sort of are you know larger networks, which govern the rules of motion.

So, there are laws of motion, and those laws are implemented through these pattern generators, when they are situated within this spinal cord, I will explain some of this in greater detail. Now, when we go higher up within the brain you have the basal ganglia, you have the cerebellum, then you have the motor, cortex premotor areas, frontal lobe.

So, control in the nervous system is a huge topic, even mechanical control systems I understand is a very complex topic, but biologically somehow the nervous system has spent; see all these govern how muscles move that is about it nothing else and its important because that is how the organism or we as human beings interact with the environment, but these are sort of non-overlapping. So, reflexes exactly are not the same as pattern generators and it is very different from function at the basal ganglia cerebellum, motor cortex, the pre-motor area and the frontal lobe.

So, let us see how each individual parts of this can be analyzed and we have an understanding of how each of these contribute to movement in general. Now, a major problem in understanding is that we do not actually have an idea of how many of these things work.

So, biologically either through disease processes or through experiments in animals there is some understanding in bits and parts as, how various parts of this nervous system entities contribute to the movement, but we do not have a complete understanding of how or at what stage or rather than what stage why of each of these things are there you know why do not you have one single system, which takes care of the entire thing, why do you need such a huge distributed network.

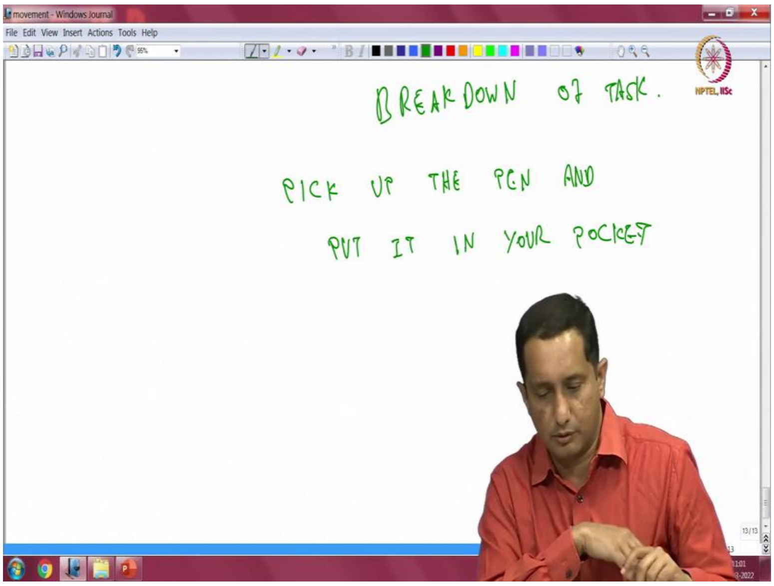
So, as to say and these are very large structures say basal ganglia sort of occupies the center part of the entire brain, cerebellum is one huge two lobes sitting in the back of your head which I have shown it to you, the spinal cord as I mentioned earlier is not just about a conducive taking information from the brain to the muscles, but it does its own local processing.

And even within the brain you know you have got motor cortex, then you have got the premotor cortex, then you have got the frontal lobe, and these are very large areas. Now, when I say large areas what does it mean? If you look at the neuronal density in any of these, they run in millions and billions.

And if you look at artificial neural networks say the kind which does pattern recognition of various kinds you can get away with some 1000, 2000 or maybe couple of lakhs of ANN networks is sufficient to do very complex tasks surprisingly complex tasks.

So, if you look at in that context, why does the nervous system require so much of material bulk to handle tasks is very surprising, but it is also humbling in the context that you know the best of robots, which are there are, they do in overall functional terms, a fraction of the activity which regular human being can do.

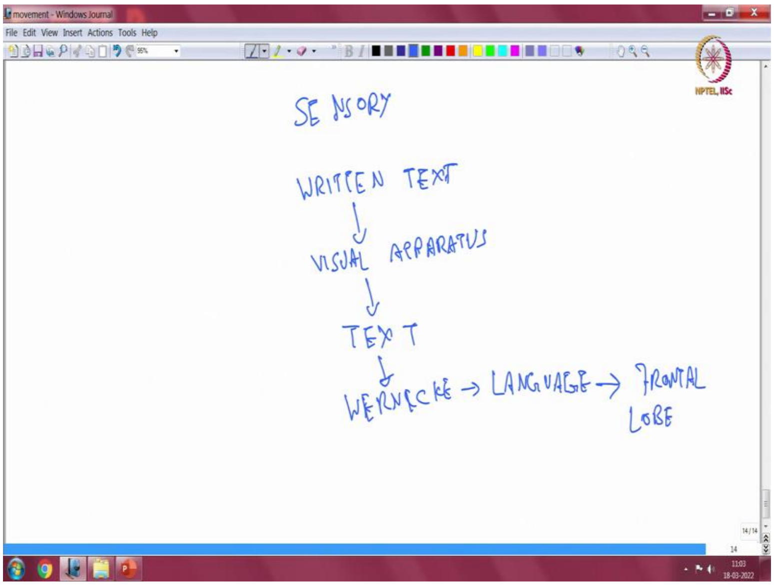
(Refer Slide Time: 09:44)



So, we will go into each of these things. So, first I will start with what I will call as a breakdown of task. So, pick up the pen and put it in your pocket. So, when we test the motor function, pick up the pen and put it in your pocket. So, that is a task, which you are giving to a person and I have a reason for putting it up like this.

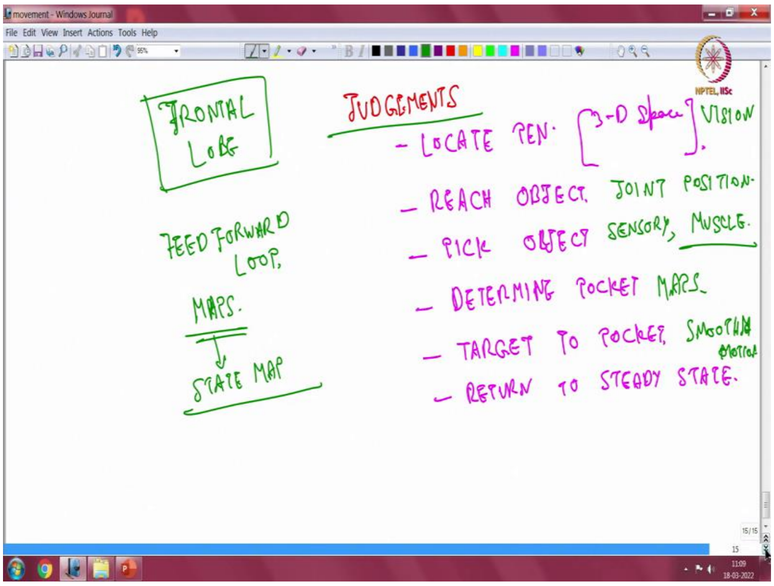
So, when we test the patient's abilities to do things this is one of the tests which we give to people and that is incidentally used to test a particular function, but let us analyze it in terms of the task. So, I just pick up the pen and put it in the pocket. So, what all are the component parts of it?

(Refer Slide Time: 11:21)



So, we will start with that is the sensory information. So, sensory information is there is written text, it goes through the visual apparatus, I use the term visual apparatus what picture should come to your mind is the retina, optic nerves, optic asymmetric, optic tract then all the way to the visual cortex and to the associated visual areas. So, text is determined in that and that goes to wernicke where it is converted into the written language and that goes into the frontal lobes.

(Refer Slide Time: 12:25)



Now, within the frontal lobe there are lot of decisions which you make. So, what kind of judgments. So, you need to locate pen, remember this is the task, which is separate from the other thing. So, you know where the pen is located, the information regarding the pen, etcetera is not given. So, you have got a written material which says that locate the pen and put it in your pocket.

So, you need to locate pen, which is basically in 3D space then reach object, pick object, determine pocket, target to pocket and return to steady state or whatever. So, there is you know you need information from various sources for this. So, you need vision for this, then when you reach you need joint position for this, when you pick you got sensory information you know what the texture is, then you have muscle information that is in terms of you know you do not crush the pen right.

So, you need to have sensory information, which is basically touch the texture of the object, but also you need to have some weight information, which is basically how much of pressure. Now, muscle information can be obtained through something called as, you need to get it from feed forward loop.

So, you have prior information that there exists pen and pens have a range of you know specifications, you know this much is the approximate weight of a pen, it's very different from holding a weight in your hand. And these are from your prior information you have got prior information in your head, and you use those information's to implement this particular reach pick task.

So, pick task has a sensory information, but it also uses feed forward loops, and it also uses maps. So, maps are pre-existing. So, maps basically indicate that you have got a state map. As I told you earlier the state map, you should think of the state map as a distributed map, which has various information's within the state map including your own body position.

So, body position is actually internally generated, where exactly is your leg at this point of time, where exactly is your head, where exactly is your eye? They are unconscious you know data points, which are generated, and it is stored somewhere unconsciously you do not have a conscious, you can retrieve it into conscious activity, but it is generally unconscious.

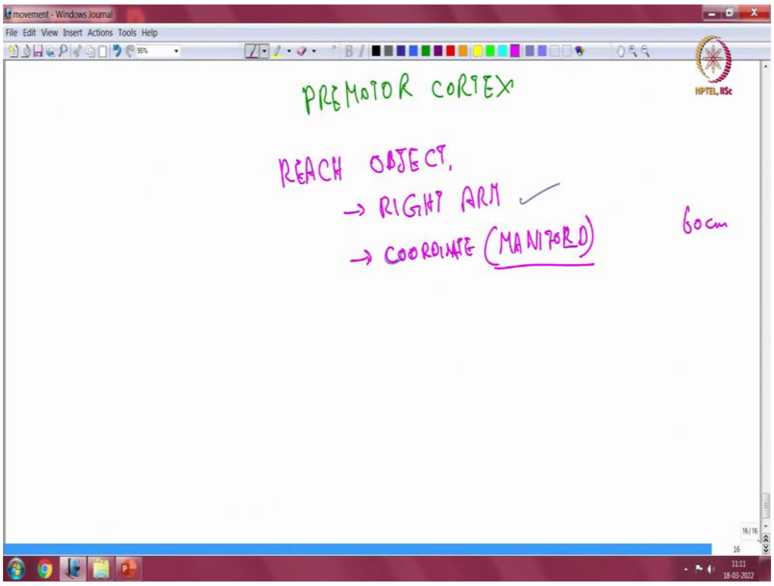
So, you have to generate a feed forward loop which says that your arms have to move to the particular object which has prior properties. Prior property set which can be invoked, which says that a pen has so much of a weight, which can have so much of weight this is the particular texture. Generally, it is cold and not harmful, meaning you know you will not get injured by the pen while picking it up.

And then the map determines that how exactly it has to go the this one. Now, remember I am just still talking about judgments, you know judgments is what is to be taken up from memory and then put into life. Determine pocket, again pocket is from your maps. The map is actually not a physical map you know in the sense, that it is not a body position map it is on clothing which you are wearing.

So, clothing which is again you get from your joint position sensations and from your you know from your state maps, state map says that you are wearing a shirt with a particular pocket on one particular side of your body. And that state map says that that is the target then you have to ensure that there is smooth motion to the pocket and where you place the pen and then return to the steady state. So, the frontal lobe here determines a lot of this high-level task.

So, that is what I call as judgment. See the frontal lobe is not actually concerned with many of the you know smaller things it is like the main file so, in a program. So, the main file just highlights that where you call the individual libraries, where you call these individual files and in what sequence of events these files are to be called.

(Refer Slide Time: 18:52)



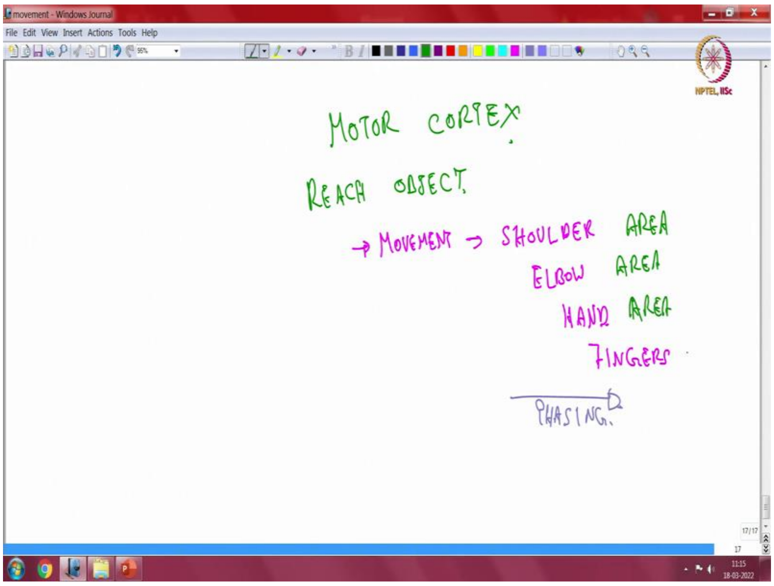
Now, when you go from the frontal lobe so, these tasks have to go into the pre-motor cortex. So, the premotor cortex takes up the information say for example, I will just take up one of these things. So, you have located pen as a task, no locket pen is already done sorry I will use reach object, reach object is the actual motor task here.

The other one is actually a sensory task. So, reach object has to be you know you have to determine right arm then you have right arm has to be activated then you need to determine coordinates it, what I mean is the manifold not actually coordinate as in synchronisation.

So, manifold would say that you have a pen, which is located at around 200 centimeters not 200 how much is this about 60 centimeters from you and within those 60 centimeters you need to move your arm into that particular region so, for a distance of 60 centimeters.

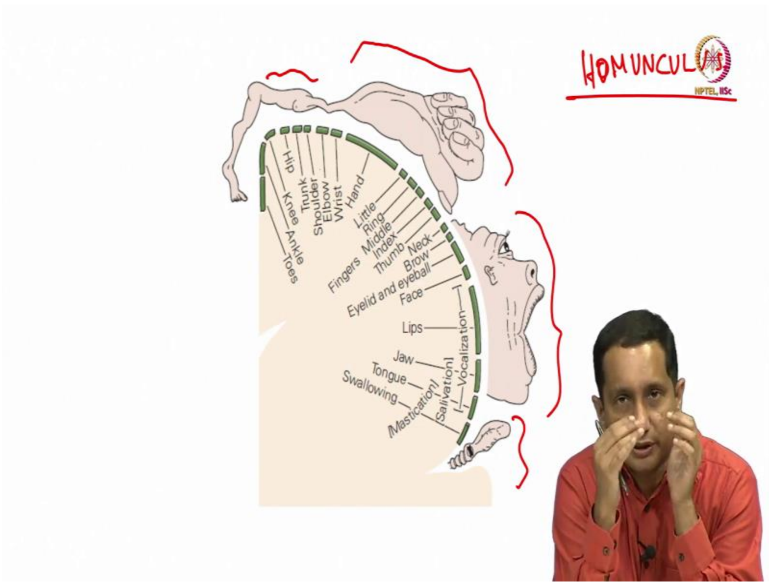
So, this is again high-level task you know there is not much of a split, but it is very different from the frontal lobe stuff. You know it has come down to a lower-level stuff, it is still we have very broad areas which are you know in terms of arm and then you have got some manifold stuff which needs to be manipulated and things like that.

(Refer Slide Time: 21:03)



So, from the premotor cortex we go down to the motor cortex.

(Refer Slide Time: 21:14)



So, here I think I will split. Go into this thing, motor cortex if you remember its part of the posterior part of the frontal lobe and is separated by the central sulcus from the parietal lobe. So, motor cortex is across the surface behind somewhere over here and this structure is called the homunculus.

So, this is the motor homunculus, and you can notice that the various parts of the bodies have differing representation. So, hand has the very large representation, face is a very large representation, tongue has a very large representation, but you know shoulder and back have a very small representation. So, it is task coded. So, what I mean is the more finer, the more accurate your region of the body is for a particular task you have to ensure that there is a larger representation. So, motor cortex is the task its split up.

So, what is the task reach object? So, reach object. So, we have determined which arm. You know you have determined the right arm to reach a 60 centimeter object. So, this needs to be split into movement at movement coordinates. So, you have shoulder and along with that you also have elbow, hand and fingers. So, there is direction and there is a phase relationship which is built up.

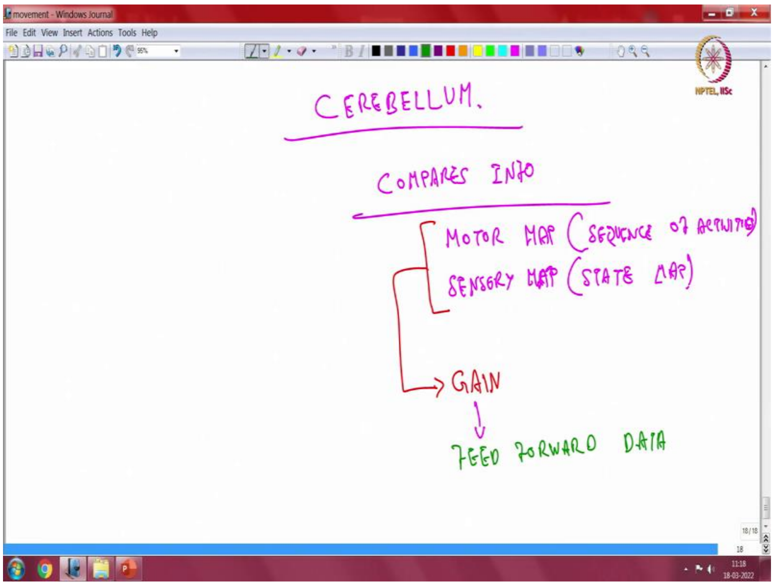
So, which parts have to be built up, which part of the motor cortex has to be activated is determined within the motor cortex, motor cortex is not just a dumb relay center which says that these things, there is a lot of inter you know this phasing business would have to be determined. You know I am not an expert on motor cortex, but you know it unless the phasing is sorted out you cannot have sequential movements, which happen.

Now when this phasing has happened, it needs to go down to the. So, you have shoulder area then there is an elbow area. So, hand area and fingers. So, this is what I meant.

So, for the example you need to ensure that you have activation here, you have activation here, wrist, hand and the entire bunch of fingers at the, which have to you know coordinate. We are just still reaching the object remember. So, even file while reaching the object, the hand is sort of prepared for the next action you do not go to there and do robotic picking, you know it is not robot picking up objects like that.

So, when I do a reach there is already so much of stuff which happens, which says that yeah, the contour of the pen is like this and I need to hold my fingers ready for the pick and place. So, that part of the splitting happens within the homunculus. Now so, we go back to the sequential this. So, you we have finish the frontal lobe what happens within the frontal lobe, pre motor areas, the motor cortex. Now, comes some interesting stuff.

(Refer Slide Time: 25:42)



So, we dive into the cerebellum. Now there are two lobes of the cerebellum and what exactly the cerebellum does is, it compares information. So, it compares information between the motor map, by map I mean the sequence of activities to the sensory map, for simplicity sake I will just write it as the state map. So, state map which say that you know where each joint is placed before I execute this movement and then there is a motor map of purpose, purpose of reaching for the object.

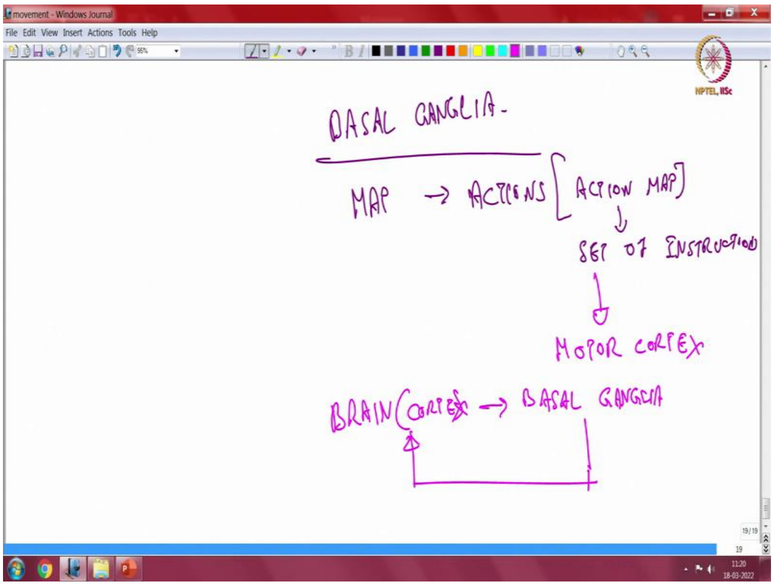
And these are compared and then based on both of these information you calculate something called as the gain, what are the changes required to the gain, which need to be implemented on the feed forward data you know there is a map. So, it is a set of instructions, which has come from the motor cortex now that set of instructions is coming down from the motor cortex into the spinal cord.

(Refer Slide Time: 27:39)

And there are some differences say for example, if I am reaching the object plane versus holding something delicate in my hand and then reaching for an object, there are some differences, because there is a additional weight I am focused on holding you know I cannot drop the object in the other hand when I am doing the reach.

So, these require that sensory map be updated and then you need to calculate for that gain. Now, the gain at each level is computed. So, that you know the final output, which goes out of the brain is smooth.

(Refer Slide Time: 28:10)



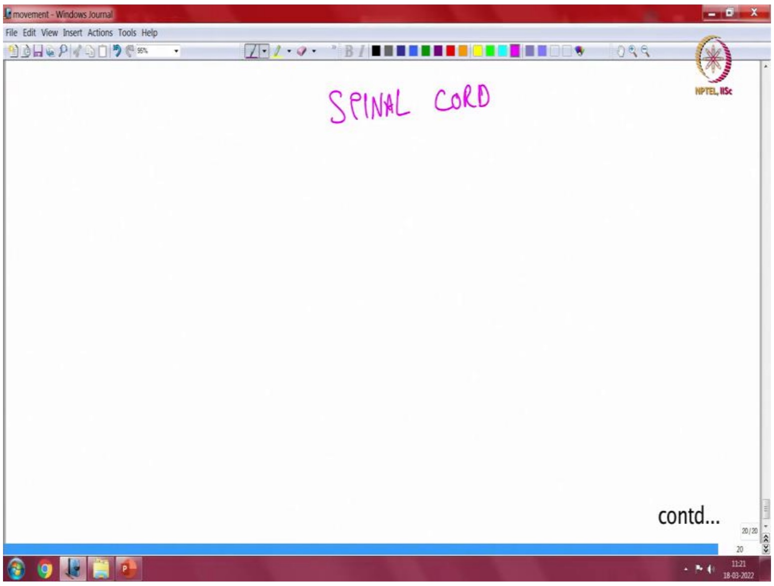
Now, in between is the basal ganglia. So, basal ganglia also gets motor, there is a map and then it compares actions generated from the action map I should say, which is the set of instructions. So, there is a set of instructions that goes into the basal ganglia and then you get an output on these parameters. Now, the output of these things does not go back into the same instructions they go into parallel pathways, the individual parallel pathways are hardwired.

So, you have got basal ganglia to cerebellum, cerebellum to spinal cord, spinal cord to the head. Sorry the map of the basal ganglia actually and these set of instructions go back into the motor cortex; it does not actually go into the periphery.

So, it is brain or cortex to basal ganglia and goes back into the cortex. So, in the context of cerebellum, it is slightly different because cerebellum can actually put in data into the spinal cord. So, and it also sends back data into the brain. So, multiple activities happen. So, you got a task set, which is generated the task set goes against various internal mapping agents like the cerebellum and the basal ganglia, each of these provide fine tuning parameters.

So, in cerebellum I can confidently call it as the gain to the system or to the set of instructions, but basal ganglia I do not like to use the term gain because the function of the basal ganglia is for other purposes. Now, why do I call other purposes because diseases of the cerebellum are different from diseases of the basal ganglia both of them are comparators, they are servo mechanisms which are built into the brain, but diseases manifestations are different. And they are so entirely different that you know the functions cannot be equated with each other though they are modulators of motor function.

(Refer Slide Time: 30:52)



Now, from there it goes into the spinal cord.