Neural Science for Engineers
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Lecture - 44
Movement Introduction

Hi, today I will be speaking about movement. Movement is the manner in which humans interact with the environment and the movement is implemented through skeleton muscles. We have discussed a lot about how neuronal muscular connections are present, how information is transmitted across neurons into the muscle side, and how muscles work.

We have discussed in brief the control systems which are there within muscles and how basic level controls are there.

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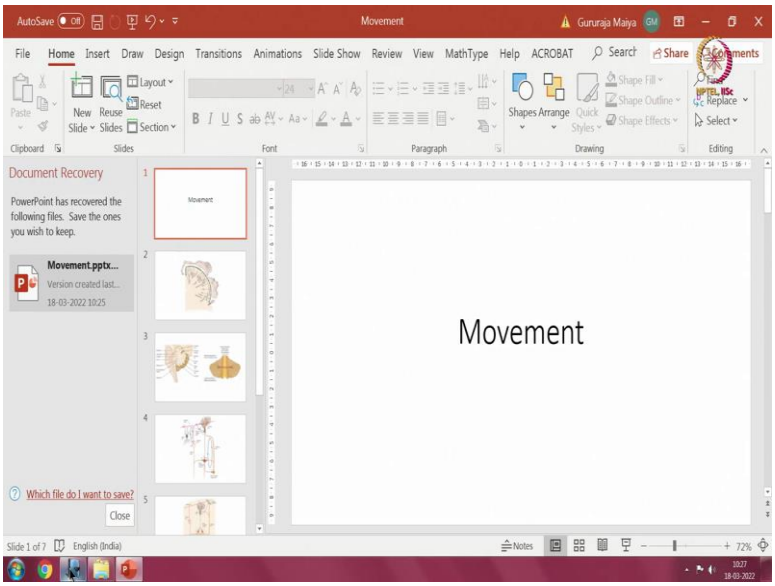

So, I will just go through the stuff which we already know and then we will progress on from there.

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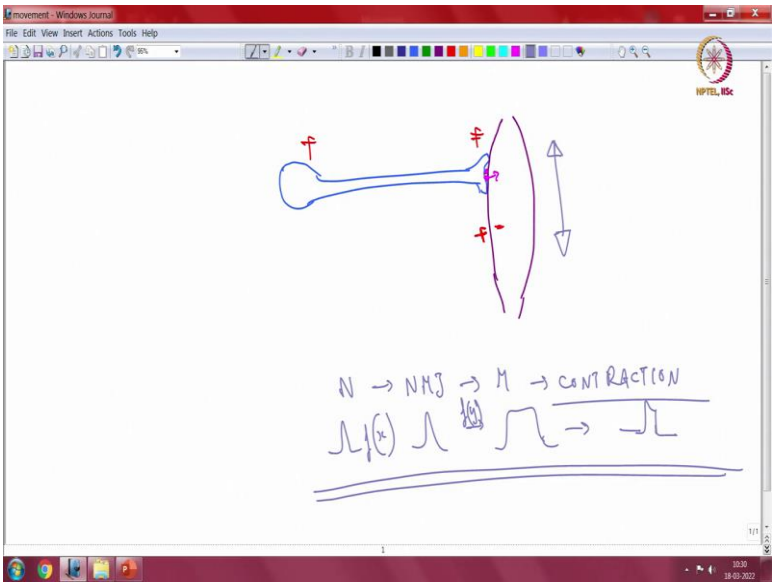

So, first is the idea that neurons link on to muscle fibre. So, that causes signals to be generated. Now, when there is a signal within the neuron, that produces synaptic activity over here and you have these neurotransmitters, which are released into this muscle and that in turn causes muscle activation.

So, you got electrical changes, which is basically depolarization within the muscle. And that in turn connects to reduction in length and I have described this in the previous classes. So, I am not revising that whole thing back again. So, neuron to neuromuscular junction to muscle to contraction. So, that is the brief pathway which is being done.

Now, contraction as such is, if you remember we discussed about how action potentials are there and even at the NMJ you create a fixed quanta of of neurotransmitters which are released, and that signal is conveyed. Of course, there is amplification which happens in the transfer of information. There is another transformation and then you get an action muscle action potential.

So, that in turn causes the contraction. So, what is seen here is it is a very linear process. So, one neuron produces a signal, produces a muscle contraction and there is a very linear transformation. But where all real world situations have a lot of uncertainty, and we need to find out how uncertainty is handled at various levels.

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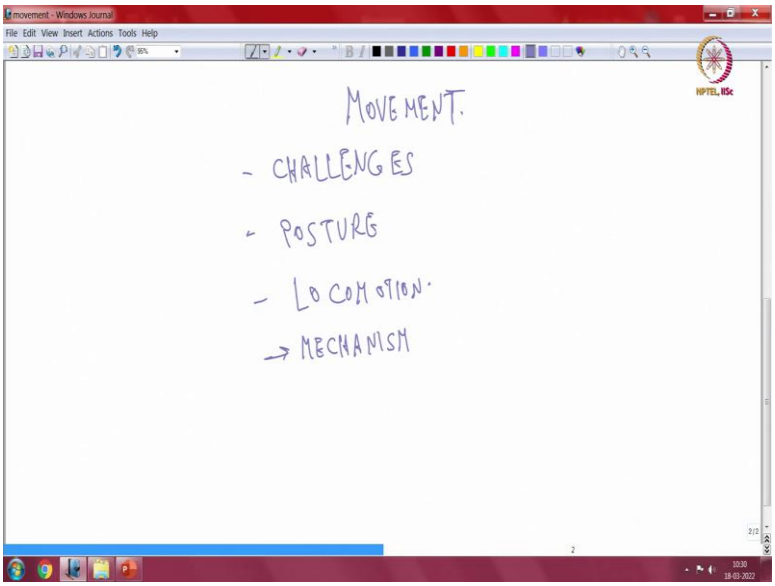

So, let me split up this the issue of movement about what are the challenges, posture, locomotion and mechanism. So, what are the challenges involved in generating movement you know purposeful movement? What is meant by posture? What is meant by locomotion and the known mechanisms of all these control systems? I will start out with challenges.

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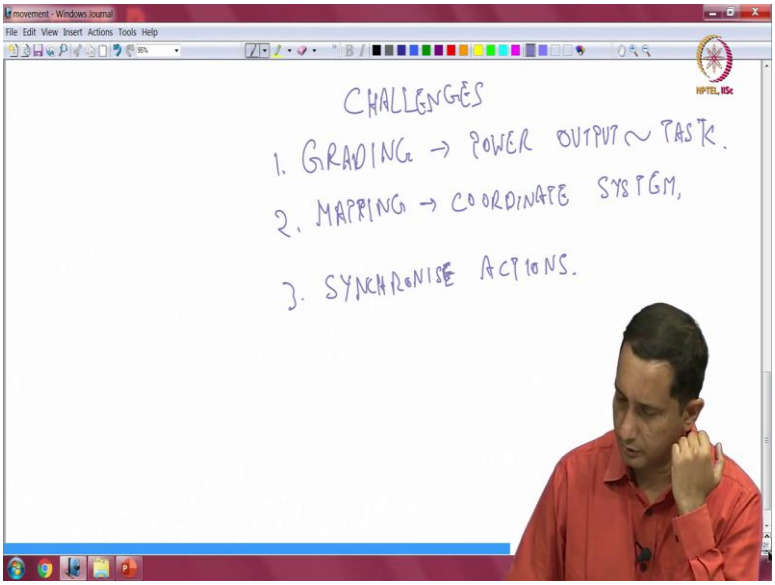

So, challenges are one is I have spoken about grading the power, you know you have to ensure there is a power output which is proportional to the task. You know there is a task and then the second thing is mapping. So, that sort of requires a coordinate system right.

So, you need a manifold and then that within that manifold or coordinate system you need to perform these actions. So, then you need to, what you call synchronise actions. And I think I will start out with each of these things and then progress onto something.

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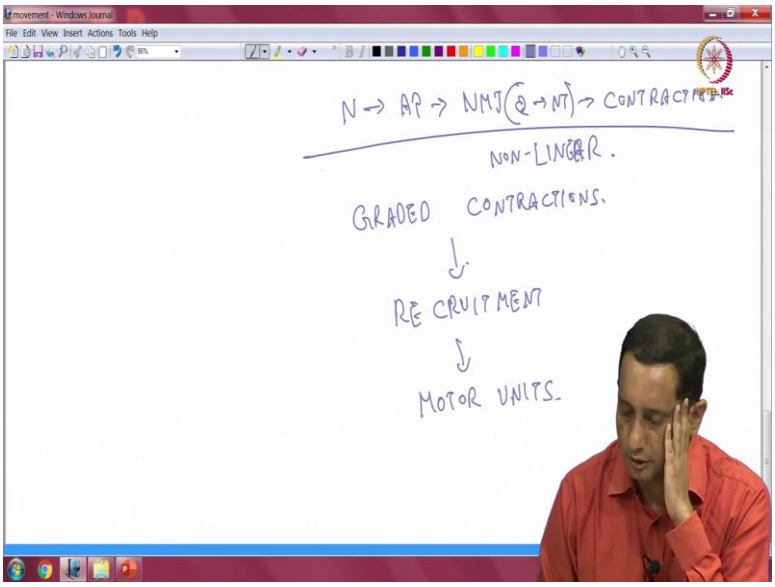

So, I am just describing about one neuron producing one action potential producing NM J which has got a fixed quanta of neurotransmitters that causes one single contraction. So, at the basic level we need to see how this can be made non-linear. So, yeah. So, non-linearity is with the idea of graded contractions. So, that is implemented through recruitment of motor units. So, we have 2 or 3 different kinds of movements we need to think of.

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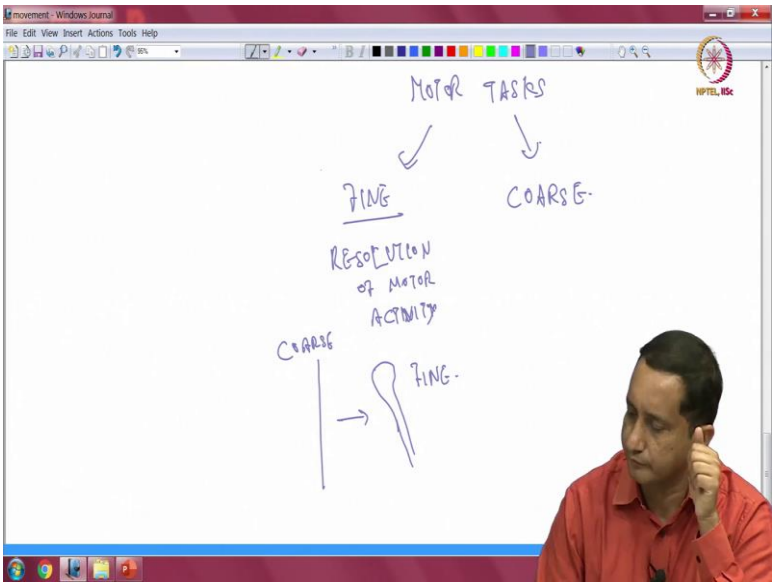

So, motor tasks can be fine, that can be coarse. So, fine indicates that you need to have a good resolution of motor activity. What do I mean by that? So, drawing a line is very different from drawing a diagram. So, this would form as you know sort of coarse and this should be fine.

So, we look in my regular handwriting versus calligraphy. So, there is a big difference between the kind of work which is implemented in regular handwriting or just scribbling versus calligraphy in which everything is set. So, fine indicates that there is a lot more control required for the motor activity, the tolerance of your proposed motor activity is very narrow.

And it not just about writing, you can have very fine motor task which have to be done. Now it need not be in terms of say performing surgery in which you have to do something which is very fine, but even in sports such as tennis or cricket in which you have to have very good hand eye coordination.

You know you have got a ball which is in a very large view space of the eye and then you have to track it and then hit it in very defined way. So, that also constitutes fine, because you know that differentiates a good player from somebody who is not so good. So, that kind of fineness how does it happen needs to be needs to be thought of.

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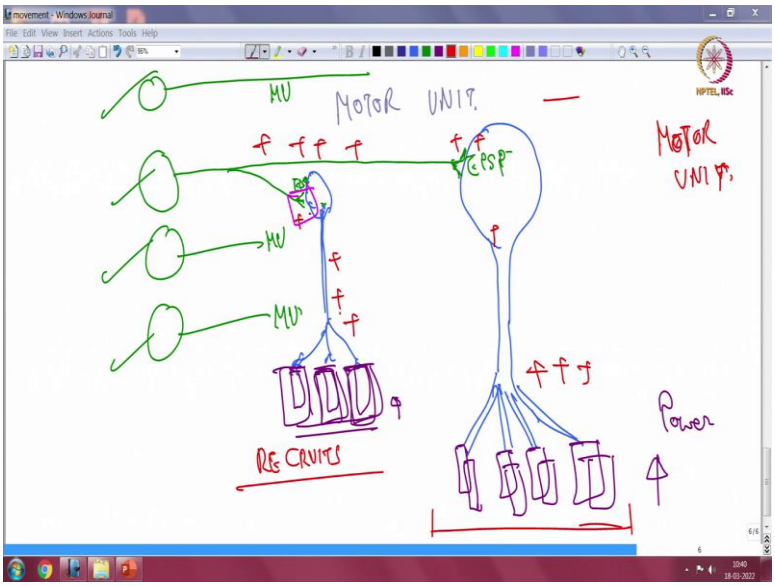

So, I will start with what is a motor unit. Single neuron, every single neuron ends up in multiple skeletal muscle fibres. So, based on the size of the neuron, you can have multitudes of fibres connected to a single neuron. The difference between this is you know you activate only a small amount of muscle fibres whereas, here you activate multiple muscle fibres.

So, power of generated is higher whereas, power here is lower. So, you have a biological mechanism of having different activities mapped on to different kinds of neurons. So, what does that mean? Suppose you have single neuron which is you know generating activity and this particular neuron has got a very fine task or something which requires less amount of power or precise amount of power.

So, what happens is it generates EPSPs over here. So, since this neuron is smaller in size the EPSP results in an action potential which is faster. So, a smaller amount of current generates an EPSP and that in turn recruits this motor unit. So, this whole thing from here to here is a motor unit.

Now, if the signal is higher, you know there is larger amount of signal which is generated that produces larger EPSP for the larger neuron and that in turn recruits the entire set of neurons when it is stimulated. So, you have a smaller amount of signal generating this smaller motor unit and the larger amount of signal generating the larger unit.

So, that is one of the mechanisms of control. So, you have numerous such kinds of neurons ending up in motor units. And you based on the task. So, you can recruit multiple motor units for the particular given task. So, that is how you can scale up responses. So, individual neurons end up in individual set of muscle cells but recruiting multiple such motor units can help you in scaling up responses across a wide range.

Now, training sort of you know you can you train to a particular task. So, there are synaptic changes which happen over here, synaptic changes which can happen over here, and you can have muscle bulk which increases if you have done some specific exercise.

So, muscle improves its bulk with training and exercise. And repeated stimulation of a particular pathway results in increased bulk of the muscle. So, that is how you have better control and better finer movements generated from the pathway. So, different motor units are used to assign a task. So, this way of assignment is what has been shown over here.

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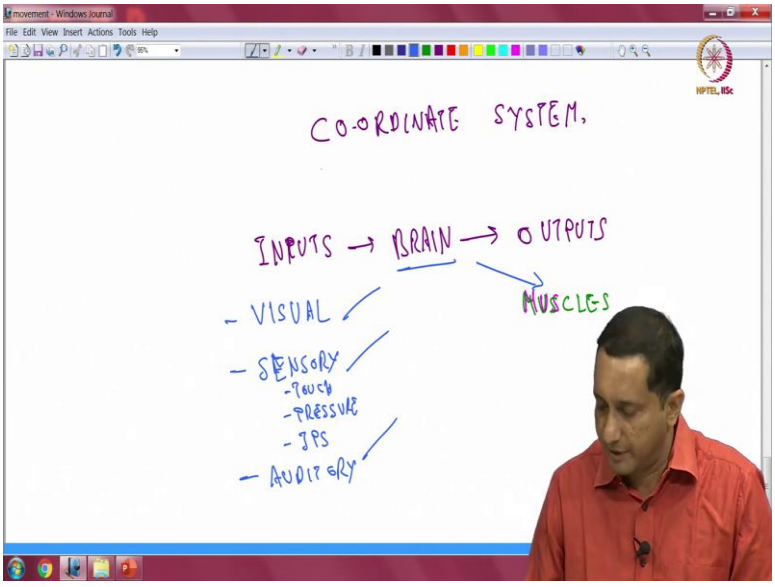

The next challenge which I am addressing is the coordinate system. Now, the brain is enclosed within the skull. And it has its inputs which go into the brain and then you have the outputs. So, output in general is muscles, but inputs in turn are not very specific, you got so many kinds of inputs. Primarily visual, then you got sensory; sensory as in touch, pressure, joint position sense and you also have auditory.

So, all of these things have to be integrated in the brain and the output is what is implemented by the muscle. So, you need to have a mapping system.

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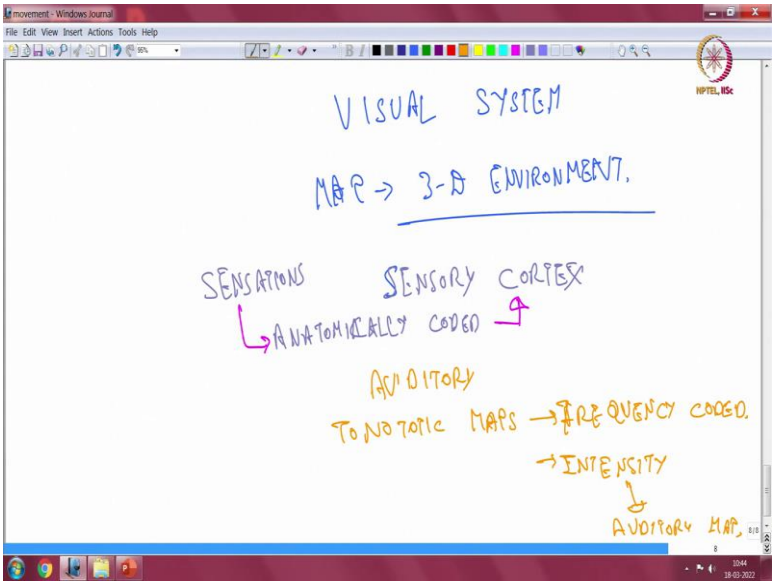

Now in individual classes, I have told you that visual the system has a map of the 3D environment. So, that is a map which is built within and stored somewhere within your cortex. Now, there is also mapping of the sensory cortex, sensations within the cord, within the brains stem they are conveyed through individual selected parts which is hard wired based on the anatomical location. So, anatomically coded and that goes into specific representations of these sensory cortex.

Auditory I spoke about tonotopic maps, which is frequency coded and also intensity coded. So, intensity can in turn result in you know you get an auditory map. So, you have got free different frequencies which are taken up from the ear and then you get information from both the ears which will give you a directional sense of sound and the quality of the sound far, near, etcetera coming into the ear and that is coded within your head.

So, what I want to convey here is that you have got different maps which are generated.

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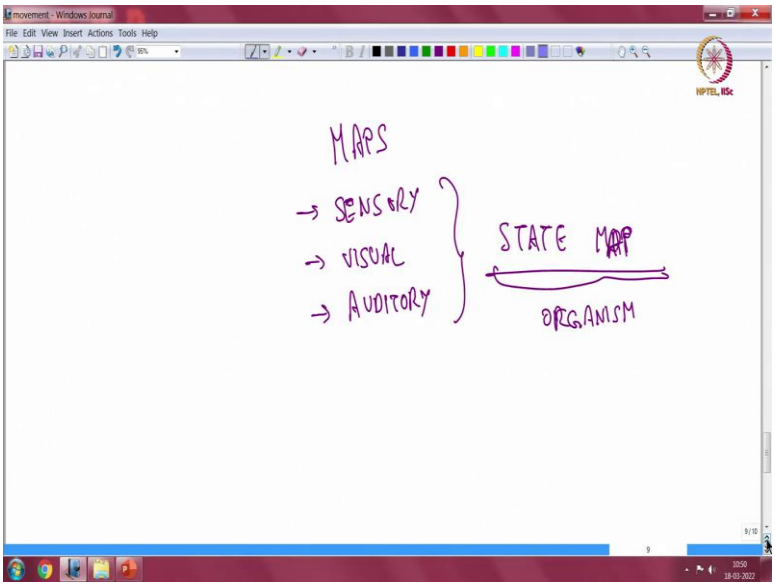

So, you have a sensory map, you have a visual map and then you have an auditory map. So, these results in something you can call as a state map for the organism or for the human being. So, these state maps are updated by individual sensation. So, visual maps of course, are much faster because one there is a larger amount of data which is coming into the eye, and it is only about this much that is about 10 centimetres. The sensory maps are more complex because you get signals from all the way from the feet up to the head and they the signals come at from at different phases.

So, because transmission within the nervous system though myelinated fibres have maximum limits. So, you get information which is continuously taken and remember these are not on off kind of systems, these are continuously on and then its only the signal amplitude changes.

Remember signal amplitude is not action potential amplitude, it is signal amplitude. It is amount of data which is coming from the various receptors sensation, sense receptor which are there in every single square millimeter of your body. They convey information and these are coded into specific regions within the thalamus within the sensory cortex and there is a map you know.

You cannot say where in your head that map is, but individual parts of the cortex get in information from specific regions of the body. So, ultimately all of these would result in

a state map. So, state maps are generated within the head. Now, an interesting problem is these state maps are not interchangeable.

So, visual map is on is a spherical map you know your environment, the sensory map is your own body representation and auditory map is from both the sides you know. So, you cannot have a 3D coordinate system. I use the term manifold for that reason. So, the brain represents outside space through these various modalities, sensory modalities within the brain and then you have a state map.

So, there was a concept earlier that the state map is there in the parietal cortex and that is what is updated continuously. But the more current theory is that you have individual maps of this kind, sensory map within the sensory cortex, visual map within the associatory visual areas, you got auditory maps which are coming into the serial temporal lobe and so, all of these maps sort of communicate with each other, it is a distributed mapping system.

So, different parts of the mapping system are updated, and you have state functions derived based upon that. Now why is it important?

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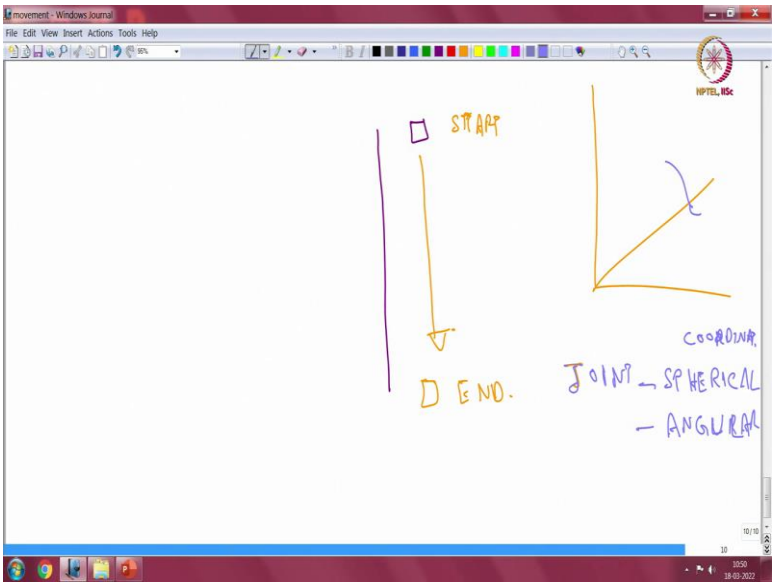

So, the act of drawing a straight line you know if you look at it, it looks very trivial, but if we look at it in terms of coordinate system and how it is implemented. So, you have a

start point and then you have an end point, and then you have a vector which is drawn from the start point to the end point.

The difficulty arises that you know as an instruction which is passed on to the brain. It is a Euclidean coordinate system. But every single joint has a spherical coordinate system; spherical or 2 dimensional. 2 dimensional is an angle based, I do not know what the angular coordinate system. So, every joint or most of your joints you can find that you know it there is an arc which is generated.

So, you know you have an arc which is generated, and that arc which is either in 2 dimensional space say for example, elbow or in 3 dimensional space say for example, the shoulder. Now, these arc movements you know of every single joint would need to be mapped on to the Euclidean space.

So, that is a real challenge. So, you have 3-dimensional x y z coordinate systems and then you have a spherical coordinate system which is the internal one and the spherical coordinate system has to be mapped on to the 3 dimensional space.

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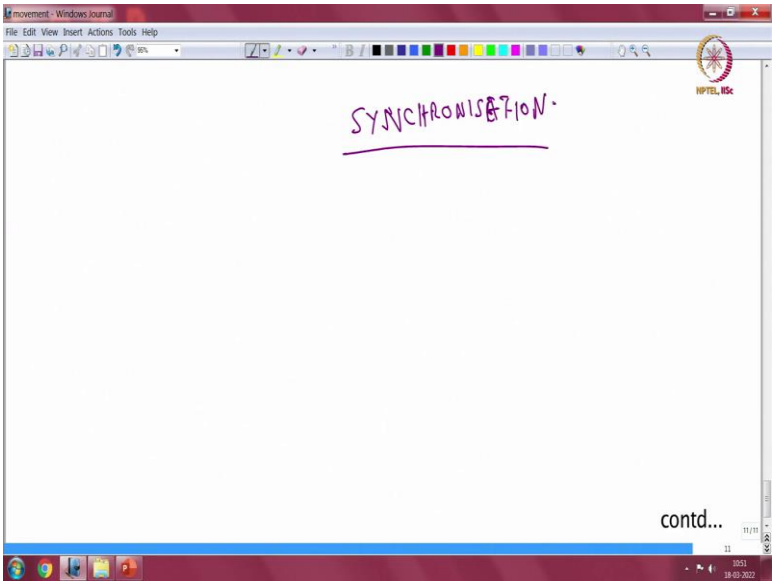

So, the next activity which I would like to speak about is synchronisation.