Digital Human Modeling and Simulation for Virtual Ergonomics Evaluation

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Lecture - 12
Techniques/Process of Virtual ergonomics evaluation using DHMs Part A (Part I)

In our course Digital Human Modeling and Simulation for Virtual Ergonomic Evaluation.

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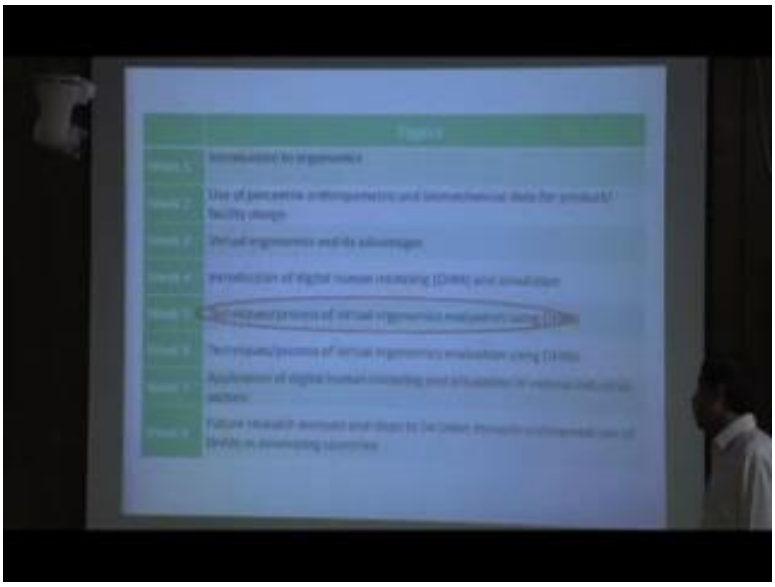

Now, today we are going to discuss our module five that is techniques and process of digital ergonomics evaluation using DHM. So, this is Module 5.

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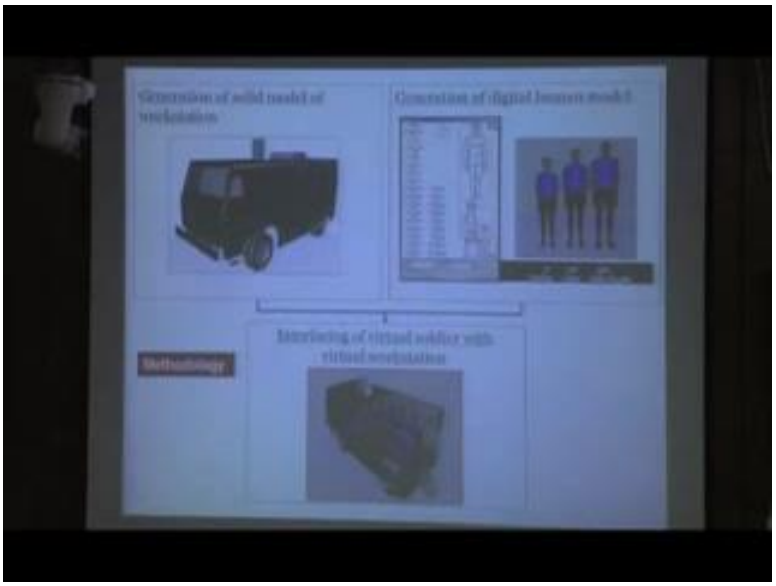

In Module 5, this is our earlier slide I will discussed about we create digital human models using the digital human modeling software have this type of interfaces are there. We can put anthropometric data and accordingly we can create all digital human as for our requirement. Similarly, we can either create this type of cad model of the product or we can import from other cad softwares to digital human modeling software. While this cad model of the product and digital human model both are ready then we give this human model to appropriate posture and using different types of reference points as we discussed in our earlier module. We position digital human models or manikins in their respective workstation then we go for different types of ergonomic evaluation. So, this is the basic steps.

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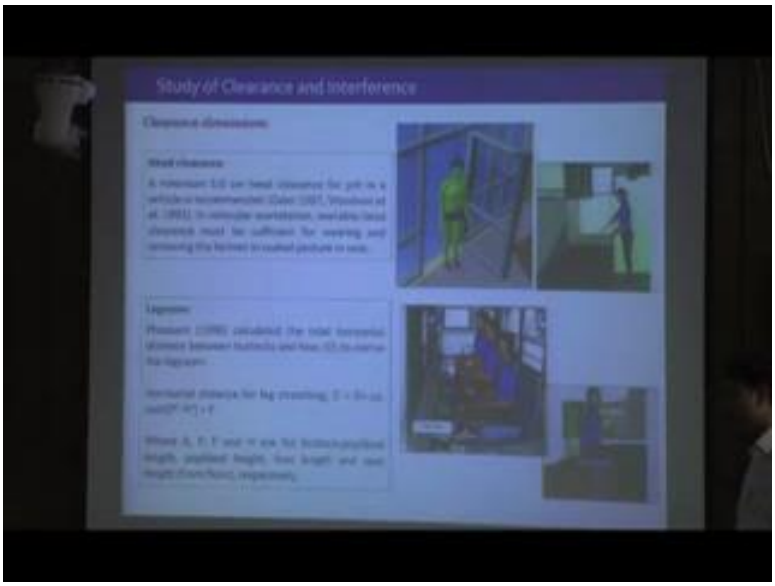

Now, while we are going for various ergonomics or human factor issues or evaluating with digital human modeling software in virtual environment then how we can do that one. So, for that purpose; obviously, we need to know the human factor issues, contextual knowledge of those evaluating variables we must know. And while we will know those variables for evaluation and their requirement then we will go for virtual ergonomic evaluation using DHM. So, first we are going to discuss about clearance and interference. So, clearance dimension, there are different types of clearance dimensions like head clearance, thigh clearance legroom. Head clearance a minimum 5-centimetre head clearance for joint in a vehicle is recommended.

So, while we are talking about automotive design then in the vehicle driver, passengers while seated or there like a bus or any other vehicle while people are standing bus, train, while people are in standing position then how much space is there above the head to the roof that is the clearance dimension. So, that clearance dimension should be minimum 5 centimetres for automobile, because during jockey or during jolt or during motion, either driver seat or passenger seat may hit with the vehicle roof. So, for that purpose minimum 5 centimetres is required.

Moreover, it is better if you can provide additional clearance space. In vehicular workstation, available head clearance must be sufficient for wearing and removing the helmet in seated posture in the seat. Here two examples given; so if this is a door while

we are evaluating that door in terms of its height that whether the height of the door is sufficient then how we can evaluate that. We can visually inspect the dimension positioning on detailed intended user population you can create this type of 95 percentile digital human model using that anthropometric data of our intended population, who are going to use this facility. So, if this is a 95 percentile or 99 percentile manikin if you position that in front of the door then we can visually check whether that head clearance is sufficient or not. If we find that it is sufficient then we can go ahead with the design; otherwise, we need to increase the door height.

Similarly, we can while we are designing this type of workstation where people are doing some activity then coherence storage is there. And its position you will have to check whether that may touch with the head of larger manikin with 95 percentile or 99 percentile manikin we can position and we can check that whether the clearance space is sufficient or not. So, in this case, we can find that in this particular workstation that overhead storage (Refer Time: 05:42) are not positioned properly, because it may collide with the head it may be acceptable for shorter manikin 50 percentile 58 percent, but it may not be acceptable for 95 percentile. So, while this type of clearance dimension we have to evaluate then we have to evaluate with larger body dimension.

Then if we discuss about legroom, so legroom is a space in front of this people who are seated whether that they can extended their leg comfortably or not. So, Pheasant, 1968, calculate the total horizontal distance between butter and toast to derive legroom. So, they have given this equation. So, while some person is seated on that the see while space in front of you is sufficient, so that they can extend the leg; using this equation where all the variables are defined. So, from that we can calculate the leg space. So, this is theoretical portion, but apart from that while we are evaluating our facility using manikin, then we can position the manikins of different percentile shorter percent manikin with smaller dimension, manikin with average dimension, and manikin with larger dimension. Then we can manipulate the leg extension and we can check whether the available space is sufficient or leg extension or normal leg movement or not that we can check.

So, in this way visually we can inspect the legroom. Similarly, whether they are in sufficient thigh clearance or not below the table top or that surface that we can also visually check after positioning that manikin, in this type of evaluation, generally we

evaluate it larger body dimension, because if larger person or larger individual is accommodate then obviously, shorter individual will be accommodate, shorter individual with smaller body dimension they will be accommodated.

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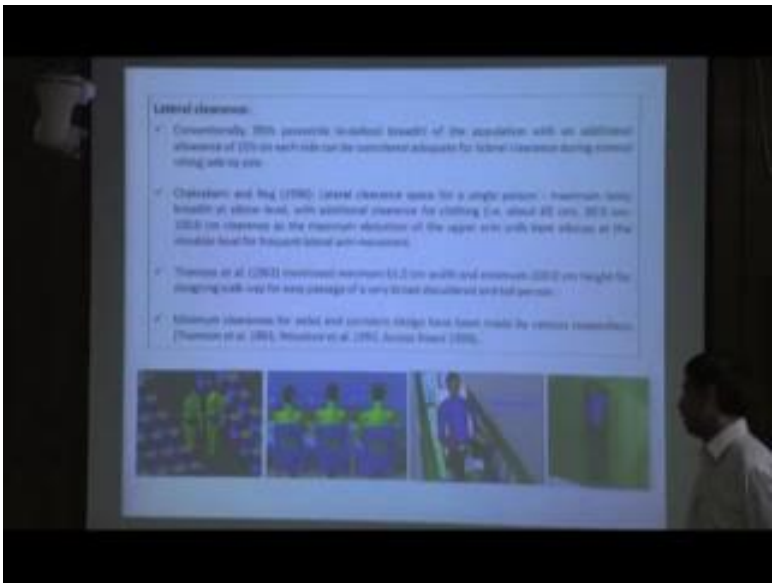

The next is lateral clearance. So, while people are seated side-by-side the space in between two person is sufficient or not; or while they are walking side-by-side that available space is sufficient for movement of two person or more person as per the requirement that we can evaluate. While we want to evaluate this type of clearance dimension lateral clearance using digital human model, then we must know the basic theoretical background. So, conventionally 95 percentile bi deltoid breadth of the population with an additional allowance of 10 percent on each side can be considered adequate for lateral clearance during normal sitting side-by-side. Chakrabarti and Nag, 1996, they mentioned lateral clearance space, lateral clearance space for a single person that is maximum body breath at elbow level with additional clearance for clothing about 65 centimetres.

So, 90 centimetres to 100 centimetres clearance as the maximum abduction of the upper arm with bent elbow at the shoulder level for adequate lateral movement. So, this type of information's are available and based on that information, we can evaluate that while we are positioning this chairs or any other facilities that the space in between two seating

position is sufficient or not, so that the individual who are seated there who can seat comfortably. And they can use the horizontal space as per the requirement.

Similarly, if we think about the width of the door, whether while we are evaluating the width of the door then we can put one 95 percentile manikin whose shoulder width or bi deltoid is the maximum you can put 95th or 99 percentile manikin and we can check whether the person can easily come in and out. So, from the visual inspection also we can understand that door dimension is correct or wrong. Thomson et al 1963, mentioned minimum 61 centimetres width and minimum 203 centimetres height for designing walk way for easy passage for a empty or a heavy broad shoulder and tall person.

So, this much width and this much height should be provided for walk way. Minimum clearance for aisles and corridors design has been made by various researchers. So, Thomson et al, Woodson et al these are the references; from these references, we will find minimum clearance dimension for corridor design will be available. So, based on those references we can initially design our product or that facility. After that through visual inspection by positioning digital human model we can check that whether that facility reason is proper or not.

So, if we check this example, yes this is a conference room; in conference room, these are the chairs here and this is the arrangement of seats. So, while chairs are arranged in that manner, then the space the middle space is actually provided for two persons side-by-side walk. So, if you want to evaluate this one then what we need to do, we need to put two digital human models or manikins of larger body dimension say 95 percentile or 96 percentile. Then we can check that while we can simulate their movement and we can check whether two persons are going side-by-side whether their body parts are colliding with each other or not.

Similarly, in other places we can. So, this is example from (Refer Time: 12:27). So, while pilot is manipulating that joystick moving sidewise or forward backward that time whether the joystick or his hand is touching with the thigh, so that can also we can visually inspect. And also a collision detection technique what we discussed in our earlier module, with collision detection technique also we can identify whether there is any collision. So, in this way, different types of clearance dimension we can study, head

clearance, legroom, thigh clearance, lateral clearance. So, this can be studied with digital human modeling software.

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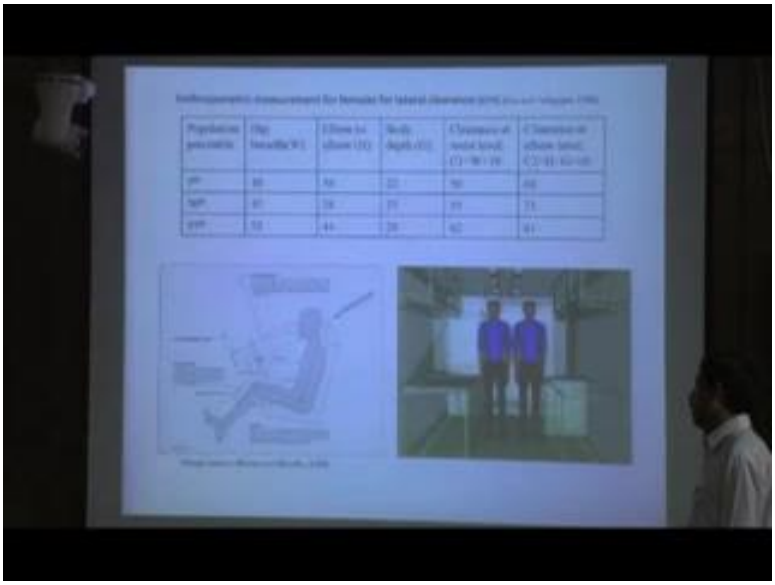

There is another reference from Dasans and Guptan 1996, they have given this table anthropometric measurement for female for lateral clearance what should be the anthropometric measurement for lateral clearance for human population. So, 5 percentile 58 percentile and 95 percentile for 3 percentile people, they have given this type of calculated values; clearance at waist level, clearance at elbow level what is required. So, these data we can define for our design purpose.

So as we mentioned, similarly if you look at the particular workstation at this type of tables are there or arrangements are there. So, the space in between these two arrangements, if whether is it sufficient for two large person with larger body dimension can move side-by-side that we can check. So, in this way whether we can explain this thing with numerous examples using lateral human modeling that how the lateral human model can be used for clearance dimension evaluation.

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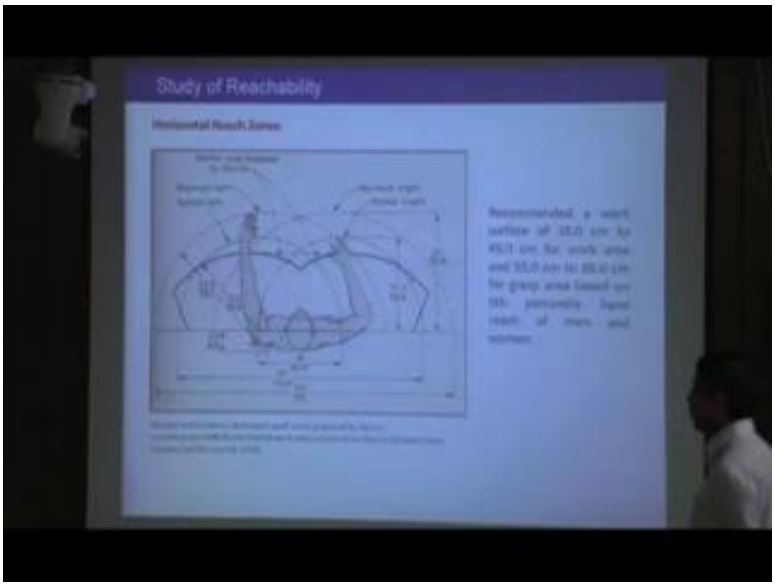

Next, we moving to reach analysis apart from clearance analysis digital human modeling software are very useful for reach analysis. So, here is also contextual knowledge of reach evaluation is important; for that purpose we are discussing about this image. So, normal and maximum horizontal work area is proposed by Bearnaise and superimposed with horizontal work area proposed by (Refer Time: 14:50) adapted from this source.

So, here while some individual is sitting on in front of a table or this is that working area then these are the spaces this is the sweeping of the left hand, this is the sweeping zone of the right hand. So, this area overall a person can access, but combining these two areas ultimately the working area has been defined by this one by (Refer Time: 15:20). Then recommended work surface of 35 centimetres to 45 centimetres for work area and 50 centimetres to 65 centimetres for grasp area based on fifth percentile for hand reach for men and women. So, there this type of information is available that how much should be the recommended limit for working area. So, that person can do their activities comfortably. So, you can go to the sources and you can read more to understand about reach zones.

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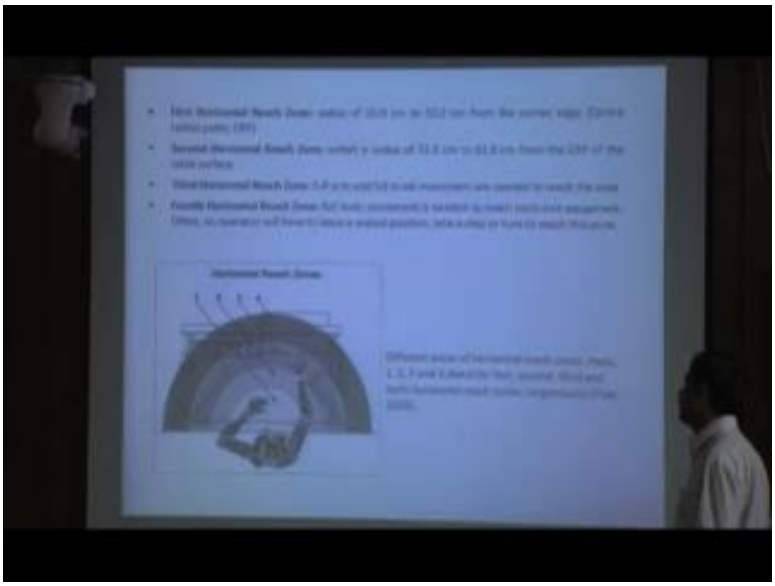

Now, there are different types of reach. We can from that person from that horizontal work surface, we can categorize like this way 1, 2, 3, 4 these are different reach zones based on the level; the first level nearby the body that area is difficult to use. So, first horizontal reach zone radius 10 centimetres to 32 centimetres radius from the centre reach centre radius from that is centre radius points. So, from this point 10 centimetres to 32 centimetres that is first horizontal reach zone. And just in front of that person whatever is that area that area below that 10 centimetres area that is actually difficult to reach that is actually ideal zone.

After that this area is called first reach zone. There is second reach zone from within the radius of 32 to 62 centimetres from the CRP that is the central radius point. From centre radius point 32 to 62 within this zone that is called second reach zone. Similarly, they have defined the third reach zone. So, this information is available from plat two thousand three different areas of horizontal reach zones one here 1, 2, 3, 4 stands for first second and third horizontal reach zones.

So, in this way we can see that where in different reach zone area or you should position of what I choose which are most frequently used by that individual those to be get nearby and gradually other items which are not frequently used that can be kept in zone four or zone three. So, in fourth, similar in this way first reach zone, second and third then fourth; fourth horizontal reach zone full body movement is needed to reach the tools or

equipment. Apart from this even extended arm reach with bending forward that is also possible.

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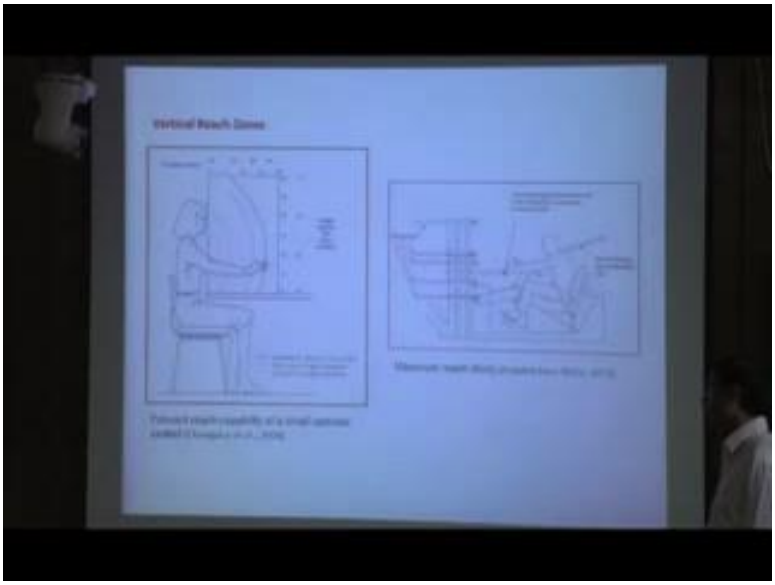

Here, this image taken from Chengalur et al 2004. So, in this reference, what we can see that this is this line actually defining the reach zone for from centre line 38 centimetres right from the centre line, and this dotted line is 52 centimetres right from the centre line. So, while person is seated and accessing that vertical area see in different direction in the centre line how much area they can access, while it is moving two side left or right side then what is the area of axis. So, and the values are given in both centimetres and inches. So, this type of data is available and those data we can use for our design purpose.

And this is taken from Bazley 2012, maximum reach study. So, for reach study this type of box we can develop and there we can study that while driver or any other person whose reach you want to evaluate how much they can reach. So, with that extended arm reach or this is taken from automotive for evaluating that automotive driving posture and they are reach. So, in that type of bump what is the reach area, so that this is the actually a setup with this setup we can evaluate the forward arm reach, sidewise arm reach or vertical arm reach.

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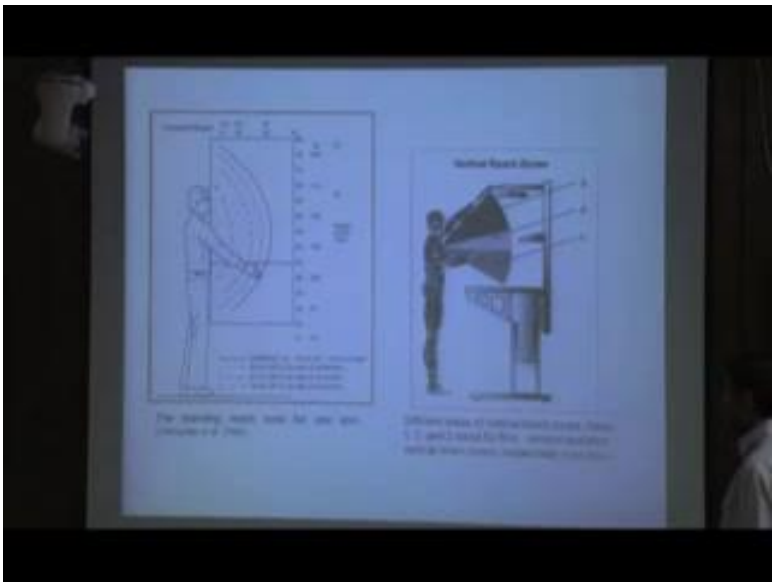

Similar to sitting, we can also go for standing reach evaluation. So, standing will so just in front of that person at the centre line, this is the vertically (Refer Time: 20:37) line. Similarly, a vertical which line similarly if it is moving left side or right side these are the defined, it is defined with this type of dotted line. This one is 46 centimetres to the right from the centre line; this dotted line is to for 61 centimetres right to the centre line. So, first one this is defined for the just in front of that person how much area it can reach in vertical plane.

Similarly, these are while it is moving from midline to sidewise then how much is the reach that is defined with this picture. Similarly, flat 2006 they have also mentioned in some other words that these are the different reach zones reach zone one, reach zone two, reach zone three. So, accordingly, we can position our intended equipments or work accessories in different reach zones as for our use.

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Now, this reach can be evaluated using digital human modeling software. While we are discussing about the reach then one is normal reach, while someone is seated or standing a normally who are a shoulder is straight or sitting with erect posture how much area he can or she can access we can evaluate. Apart from that, while body movement is allowed means they can move or they can bend forward or the backward then obviously, the reach area is more, not only that while the person is standing or lining one step forward or a backward then again the overall reach area or reach envelop increases.

So, this type of normal reach zone extended reach zone we can evaluate; not only this normal and extended reach zone, we can also evaluate comfort reach. In comfortable reach in which area person can do their activities comfortably; and extended arm reach or arm extension any other body part extension is not required. So, accordingly this digital human modeling software is also helpful for defining that comfortable reach zone. Apart from normal reach zone, extended reach zone, we can also evaluate comfortable reach zone using this type of softwares.

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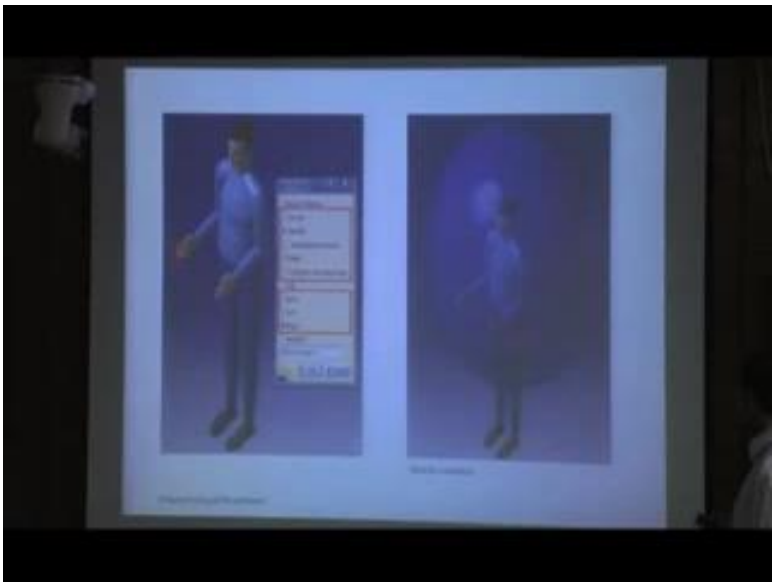

So, here we are discussing about example from CATIA software. In CATIA software, how we can create reach envelop for our evaluation. So, there is this type of tools that is called computer reach envelop. So, if you click on that one then it will show this type of window. Range of motion, current, specific, physiological, maximal ideal, so we can select. So, if we select the ideal then side, with there are also option both side left, right side, so we are going for right. Then for which body segment, you have to identify you have to define that body segment here. So, middle finger or index finger, which finger or finger tip or any other portion of the body, you can mention here. Then it will create this type of reach envelop, this reach envelop actually shows the area overall access area by the person.

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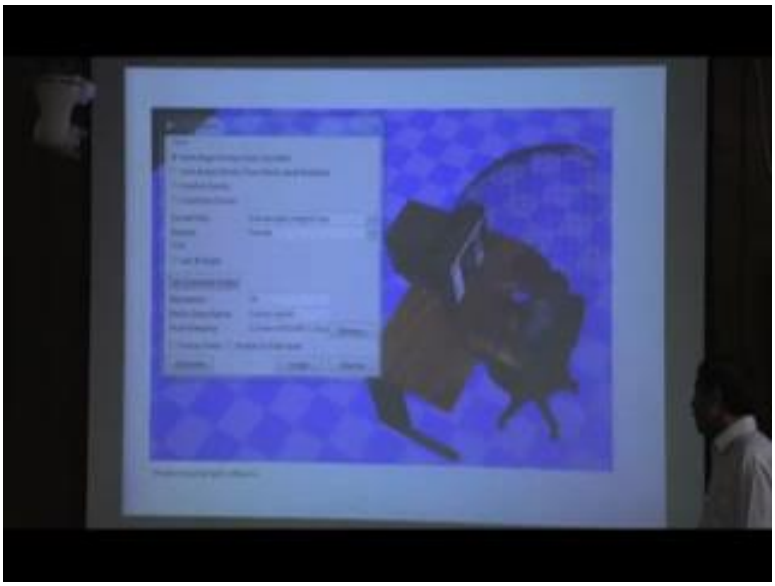

Similarly, in other software, here we are describing using jack software. In Jack software, there are also these types of different types of reach zone we can create. Joint angle driven from shoulder meant that person joint angle hand is moving from the shoulder. So, upper body or (Refer Time: 24:33) hand is moving from the shoulder joint. And how much reach accordingly you can calculate, you can create a reach envelop, joint angle driven from waist axial rotation. So, not only from the shoulder the actually body is moving from the waist joint. So, it can it will create a more bigger reach zone, because body hand is moving starting from that waist joint and axial rotation is also provided do reach zone will be more.

Similarly, you can go for comfort solid creation constant driven. So, constant driven if you talk about these tools, so how we can put that put any particular constant for a particular body joint. If you would mention that you want to evaluate a reach for a finger tip, but not from the shoulder joint from elbow joint. So, first we have to define that all constant is that hand will move only from elbow joint. So, only movement from the elbow joint will happen not form the shoulder joint. So, in that way, with constant driven also we can create reach envelop. So, here it is an example of you can also set the resolution all this. So, this is for finger human right finger; for that particular finger which is creating that reach zone and again in that software there are different types of visual, you can display it is in wireframe mode, you can visual it in shaded mode, you can re penetrate in transform mode. So, there are different modes of representation also.

So, in this particular example, we can see while this I mean manikin is seated on this seat and working on computer then this is the zone where we can access. So, during our work place design, we will have to position or frequently use items just in front of the human, so that he can easily access. But other items you can keep little bit away, but within the reach envelop, so that all the items around him or her, they can access very easily.

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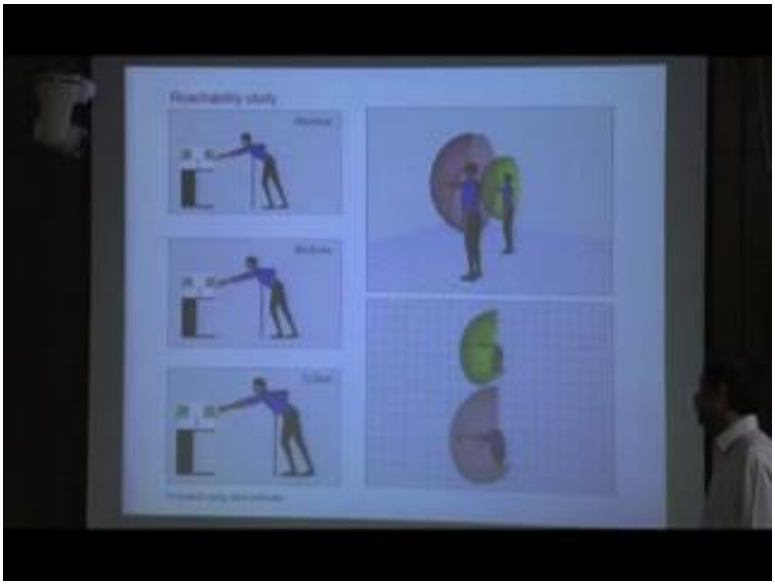

Here is again example from Jack software only. So, here it is shown, if this is some products or equipment and if you want to put a barrier. So, where should be the position of the barrier, so obviously we want that no one to touch the product, it may be hot, it may be some chemical it may be some hazardous material. So, you want to put a barrier, so that people cannot access that one. Or this is some display, so we are putting some boundary, so that people cannot touch that display. So, for that purpose or exhibition for that exhibition or display, so they cannot touch. So, apparently for five percentile or for people we shorter dimension, this is the position.

So, we can check it this is the position of the boundary or barrier, but while this is 95 percentile, their reach is more. So, accordingly, we have to decide we have to ultimately have to position that boundary or that barrier here, so that 95 percentile or 95 percentile manikin cannot access that one. So, if 95 percentile person cannot access that one so obviously, 5th or 95 percentile in which we will not be able to access. So, this type of

restricted reach or positioning this type of barrier, we can think about using digital human modeling software.

Similarly, with human modeling software, we can create this type of reach envelop; this is from side view and this is from top view. So, from top view, we can understand this is the total reach area; for that individual for right hand finger tip. So, if this is the standing workstation, if we want to position, his accessories or work element, so those should be kept within this reach envelop, so that they can access those items for their work.

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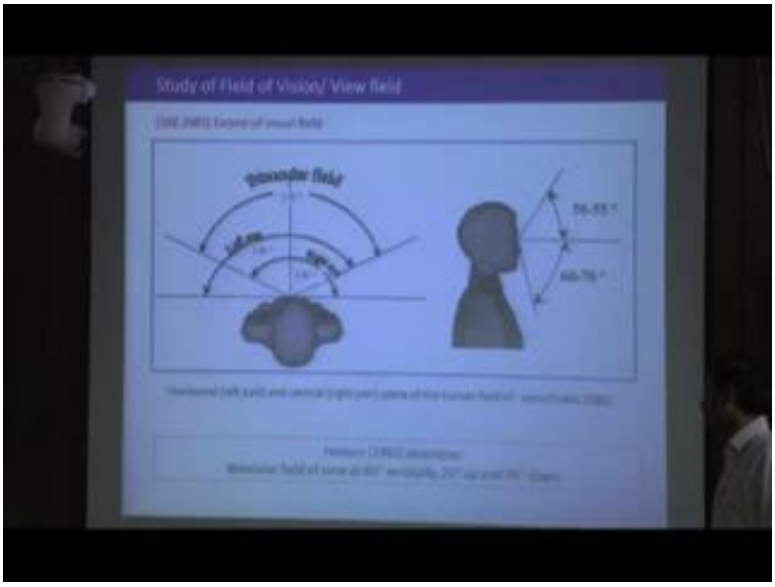

So, after discussing about various clearance dimensions the reach then we are moving to ergonomic evaluation of vision and view field using digital human modeling software. So, for evaluating vision or view field with digital human modeling software, contextual knowledge is also important here. Student must know that how is our normal field of view then how our eyes move, how our neck moves, because vision in general how we visualize something. That light is from that object actually reflected light from that object coming to our eye or our sensory organ through that light is passing and ultimately it is giving signal to our brain.

So, reflected light is from the object entering through our eyes falling on specific portion of the eye that is called retina. And there is some chemical change and based on that chemical change there is action potential generation and that action potential is travels or

proceed along the knot optical knot and it ultimately goes to brain, and give the impression of the image.

Now, while we are looking at any object how we look we have eye movement, we will also have neck movement. We can move our neck we can move our eye, eye can move independently. Whenever neck is fixed only eye can move; whenever eye is fixed neck can move; at the same time eye and the neck both can move simultaneously. So, that is the basic understanding.

For any object, while we are evaluating with digital human modeling software we can move the neck, but in many times neck movement may not be required only with eye movement that person can visualize. So, during the evaluation have to understand whether that for that particular view field evaluation whether neck movement is required or not, because many things we can see only with eye movement. So, what is the range within which we can visualize any object only with eye movement or where we actually required neck movement along with eye movement?

So, for that purpose, you have to understand the thing. So, generally for human being, for our, with right eye we can see 150 degree for right eye. Similarly, with left eye what in horizontal plane we can see 150 degree. So, overlapping area of right eye and left eye that is coming to 120 degree. So, out of this 150 degree and this left 150 degree the mean portion 120 degree is actually visualized by both the eyes, these area is called binocular field of view. In this field, we can visualize with both the eyes, but this area is visualized with right eye and this area is again visualized only with left eye.

So, this is for horizontal direction. Now, in vertical direction 50 to 55 degree up and 60 to 70 degree down you can visualize. Henson, 1993 mentioned binocular field of view is 60 degree vertically out of that 25 degree up and 35 degree down. So, as per this reference, he mentioned normal binocular field of view 25 degree, this is the maximum movement, but generally we can move 25 degree up and 35 degree down for all normal point.

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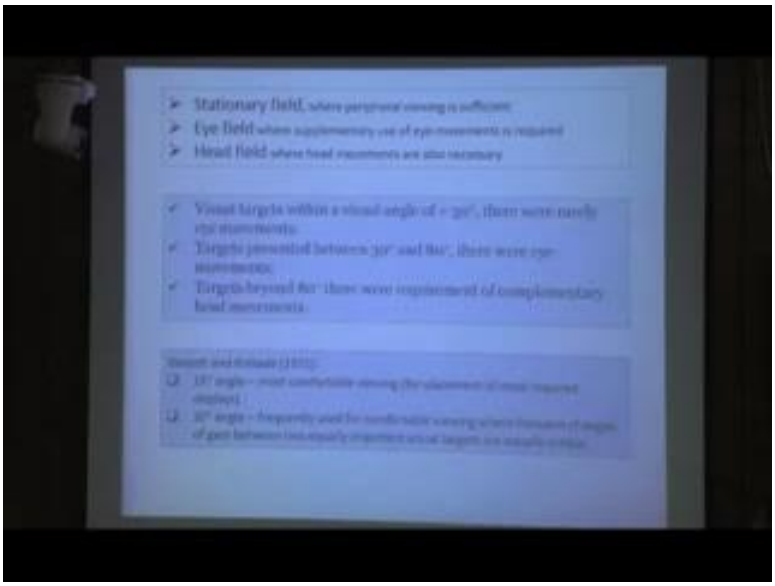

Now, there are different types of view field, stationary field, eye field and head field. So, what we discussed here, this view field actually this is obtained while our head is fixed means there is no head movement, only eye is moving. With eye movement we can visualize the portion. While even not eye movement also, if you move your eye then you can look at wider area. So, while chin is fixed or head is fixed, person is looking forward at that time this is the field of view. Similarly, while head is fixed or neck is fixed and person is looking in front then this is the area is vertical view. Now, we are discussing around the particular focussing point.

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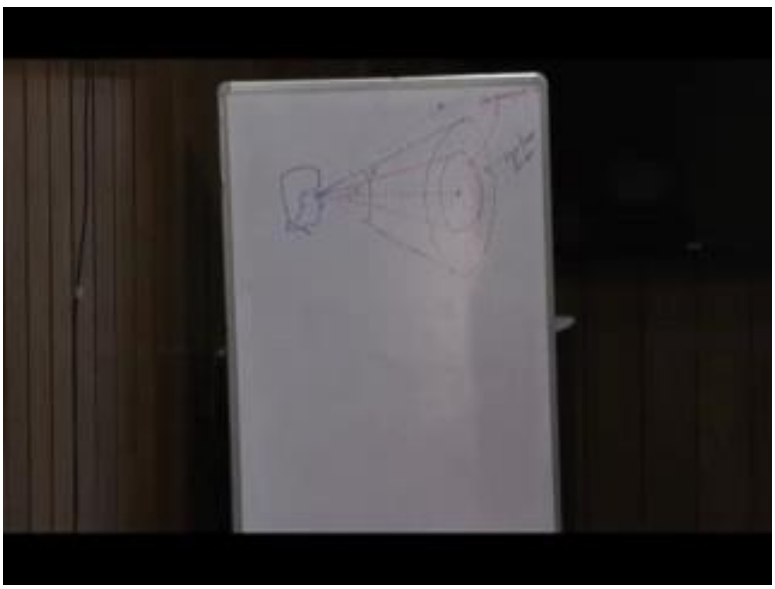

This thing will be much more clear, if we draw this one. So, this is the line of sight view while or individual is fixing his or her eye at a particular point, this left is called line of sight. So, this may be fixed; here also this may be the fixation point. So, if he looking at this point you can fix this eye at this point also. So, this is line of fixation. Now we are going to discuss about the first one - stationary field, where peripheral viewing is sufficient. In stationary field, what we do, eye is stationary and head - head is also stationary. In eye field, as supplementary use of eye movement is required I mean head field a head movement is also necessary.

So, generally, what happens? Where you are fixing up our eyes, this is the line of fixation around that these 15 degree up and 15 degree down, this is 30 degree angle. Around the line of fixation this 30 degree view zone, view zone 15 degree up and 15 degree down this 30 degree area whatever objects and whatever visuals are there we can visualize very clearly without significant eye movement or head movement. This is known as stationary field or station field, where there is no eye movement as well as there is no head movement. So, this is called stationary field. So, generally stationary field is 30 degree. So, this is stationary field that is 30 degree.

Then 30 to 80 degree, where there are eye movements that is called eye field. Then if we will extend this range from this 30 degree, this is the 30 degree view cone zone after that in this zone beyond 30 degree, but less than 80 degree. Within this zone whatever is position, we can visualize with our eye movement, this is known as eye field. So, first one around the line of sight up to 30 degree whatever is there we can visualize clearly without significant eye movement and head movement. So, head movement is not required, head movement or neck movement not required and eye movement is also not required within this zone. Eye is always moving that is different for fixation eye is always changes, but while eye is fixed at a particular point around that up to 30 degree angle whatever visuals are provided that we can visualize without significant eye movement as well as neck movement this area is known as station field.

After that from 30 degree to 80 degree within this zone whatever visuals are positioned that we can visualize with our eye movement, with the effort of the eye movement we can visualize this zone this zone is known as... So, first one this is stationary zone, second zone is known as eye field - this is 30 degree to 80 degree. Beyond 80 degree whatever visuals objects are there if we want to visualize for that purpose both our head

movement as well as eye movement is required. So, beyond this if any object or visuals at this area beyond this zone beyond 80 degree, then beyond 80 degree from line of sight, if eye at fixed at particular point this is line of sight around that line of sight beyond 80 degree means 40 degree up and 40 degree down beyond 80 degree if we want to visualize.

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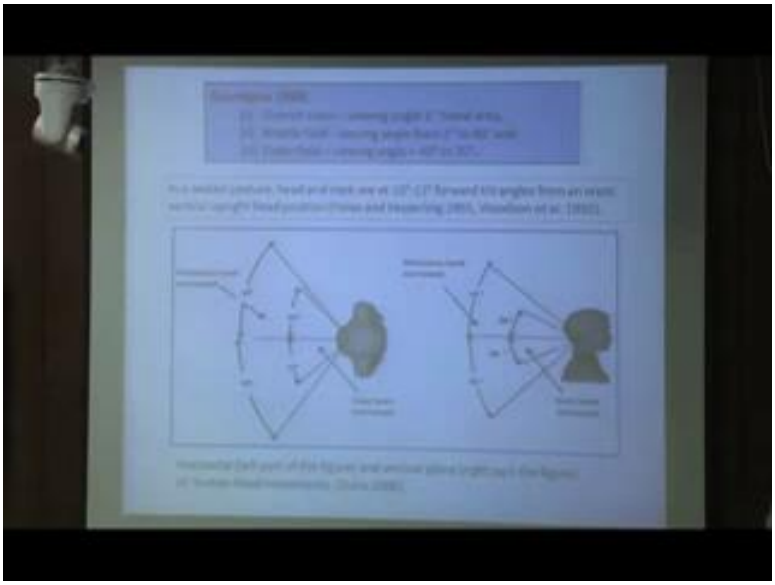

Any object or items or any other visuals then we need both our eye movement as well as neck movement this zone is known as head field. So, in head field, head movement is required eye movement is required; in eye field only, eye movement is required head or neck movement not required; and in stationary field, both head movement and eye movement both are not required. So, this is what we discussed that is around the line of sight. Already we are fixing our eye around that line of sight; this is the zone where we can visualize either with our eye movement or with head movement or with combination of both.

Vancott and Kinkade, 1972, they mentioned 5 degree angle most comfortable for him while we are positioning. Any display in 15 degree angle is comfortable. And we can extend it up to 30 degree; frequently used for comfortable fields at frequent changes are (Refer Time: 41:44) between two equal important visual terms are critical. So, while for our general purpose we should try to keep our display in front of us that is within 15 degree angle. But we can if two three display are there or two three visual targets are

there which are equally important, and we need to sit or get from one to another then we can keep all those displays or all those visual targets within an angle of 30 degree.

Now, Grandjean, 1988 mentioned distinct vision viewing angle 1 degree foveal area; middle view viewing angle is 2 to 40 degree, and outer field viewing angle 40 to 70 degree. So, he mentioned if we put around our line of sight within 1 degree viewing zone whatever visuals are there we can visualize very clearly distinct vision is possible. But from 2 degree to 40 degree within that zone that is called middle field, where vision is little bit blurred not that much distinct like 1 degree fovea area. Then outer field while that viewing angle is more than 40 degree to 70 degree then we cannot vision is not that much clear or we can nearly identify moving objects field in that area vision is not that much clear.

Next, information this is taken from Hsiao and Keyserling 1991 and Woodson 92. So, there they mentioned the 10 to 13 degree forward tilt angle, while is generally object for positioning upright vertical head position. So, our head is always not (Refer Time: 44:02). So, while we are sitting or doing our activities then generally our head is little bit forward tilted, and that angle is 10 to 13 degree this information is important for positioning digital human model because while we are initially creating digital human modeling and positioning that human model in the respective workstation. Generally head is in clear posture, with neck angle zero degree.

But for our evaluation purpose as this is the normal human behaviour that human neck is with the vertical line which is generally 10 to 13 degree forward tilted. So, forward evaluation, so initially our neck posture should be given forward flexion of 10 to 13 degree then we should go for evaluation because that is the normal situation then it is the normal position of the head then we will go for view field evaluation. Then whatever so far we discussed that is the movement of mainly eye and view field.

Apart from that if we look at this one that how much area meant for our neck movement what is the range of our neck movement horizontal left part of the figure and vertical plane right part of the figure of human head movement or neck movement. How much our neck can move, because while view field while we are discussing about vision - human vision then already we have mentioned that human vision is also dependent on neck movement, because our eye can move or head can neck can move and that

movement is independent and it may also move simultaneously. Head movement as well as eye movement may happen simultaneously. So, here is information regarding the range of head movement seen horizontal plane neck can move 45 degree sidewise easy head movement and maximum head movement is 60 degree side wise. Similarly, for a up down vertically which is a head movement 30 degree up and down and maximum head movement is 50 degree up and down.

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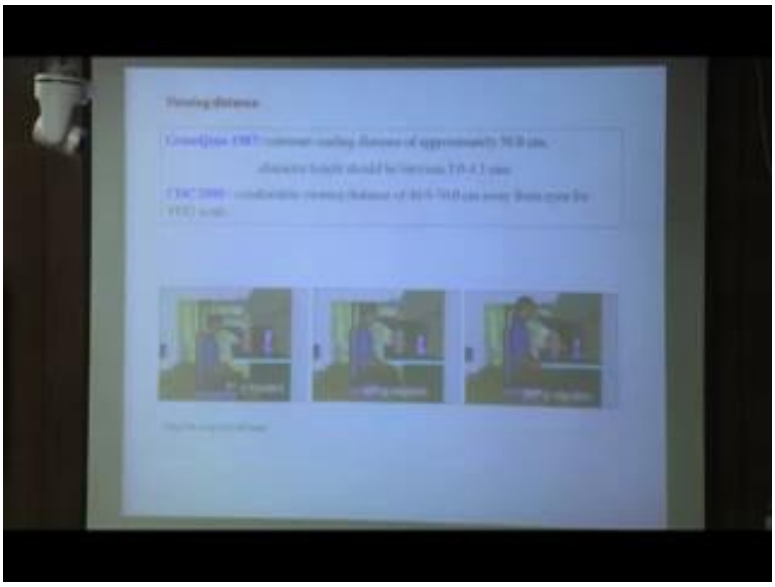

Now, we are discussing about viewing distance. Then from this reference Grandjean 87, we find the common viewing distance approximately 50 centimetres. So, while individuals are reading some this place or any other reading material that may be printed material also, so where how should be the distance from eye to the particular object viewing object. So, common viewing distance is 50 centimetre, character height should be between 3 to 4.3 millimetre. Centre for Disease Control, USA, 2000, they mentioned comfortable viewing distance or visual display unit work is 40 to 76 centimetre.

So, in general we can find that 46 to 76 is also matching with this one. So, for general purpose, visual display work, visual display terminal are using our computer, laptop or this type of purpose also we should position our laptop from eye point to 66 centimetres to 76 centimetres away for comfortable viewing. And for neck angle, we have already mentioned that monitor or display should be positioned below eye level. On the board what we drawn that was related to line of sight those wherever we are looking at around

the line of sight those are the angle, while we are discussing about stationary field, eye field, head field those are around the line of sight.

Here what we are discussing in this example, while we are positioning the monitor or any other display then monitor should be positioned just in front of the individual midline of the monitor and midline of the individual should match. Viewing distance would be 46 to 76 centimetres and what should be the view cone. So, monitor position should be such that it should come below the horizontal eye level within 15 degree at the most 30 degree.

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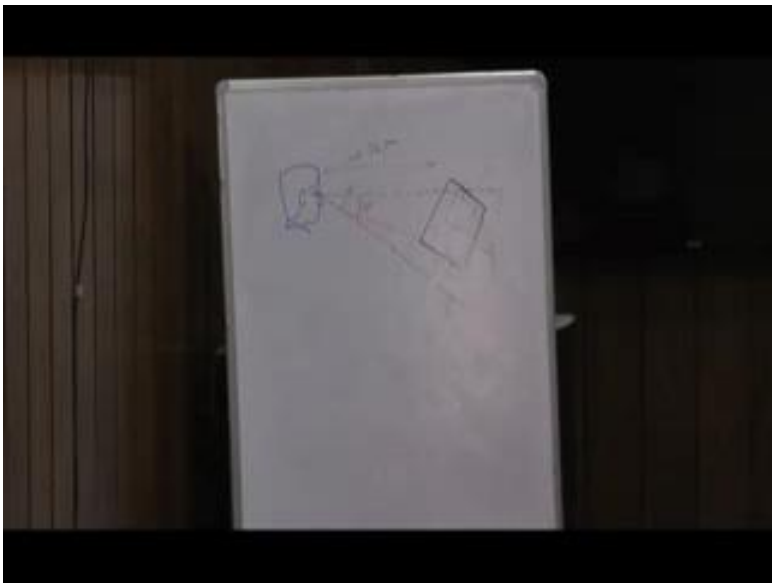

So, if you want to position our laptop monitor or computer monitor then how should be positioned. So, first we have to decide that horizontal line of sight. If this is the horizontal line of sight below that, so this is assume this is 50 degree angle within. So, distance should be the distance should be 46 to 76 centimetres and the display should be positioned like this way. So, if this is the monitor, monitor should be positioned within angle of 15 degree, this is the top line of the monitor screen, there should be below this one. So, this is the horizontal eye level monitor should be positioned below that horizontal eye level within an angle of 15 degree and it can go maximum 30 degree. If this is the big display or there are two three display then the display should be positioned within this zone. So, two three displays are there then those display should be positioned within this area that is within 30 degree.

So, comfortable viewing angle is 15 degree below horizontal level and we can go at the most 30 degree below the horizontal eye level for positioning our different types of displays and viewing distance is 46 to 76 centimetre. So, based on this information of our eye movement, neck movement and different types of view field, we can go for virtual ergonomic evaluation of view field or (Refer Time: 51:31) for a manikin. So, give me different workstation, we can position different percentile manikin and we can check their vision. Here it is shown that means, 30 degree view cone which displays are visible and which displays are not visible. So, accordingly we can position the visual display unit.

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Now, how we can use the software for this vision analysis purpose. If you take the example of CATIA software, in CATIA software, this is that human model. So, first we are selecting that human model and for that human model we are going for vision analysis. So, there is one tool called vision window.

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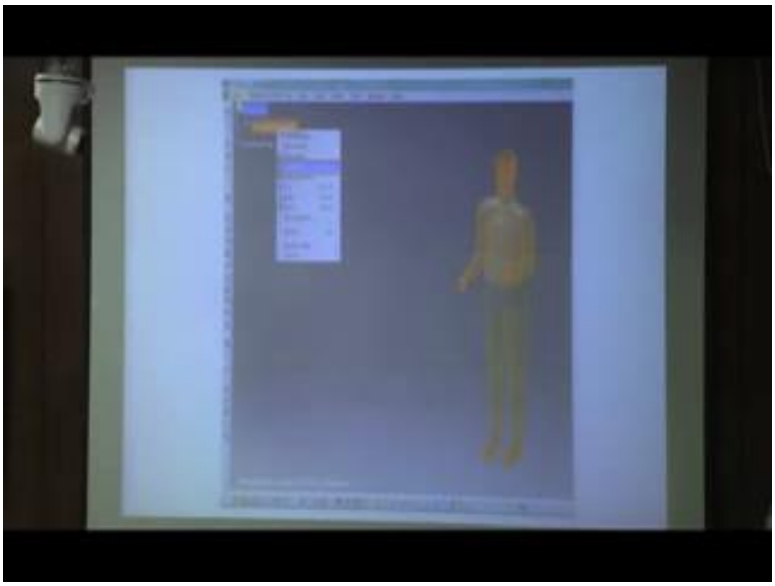

If you click on that vision window, then for that purpose what we are doing first we are selecting that human, we are going for properties.

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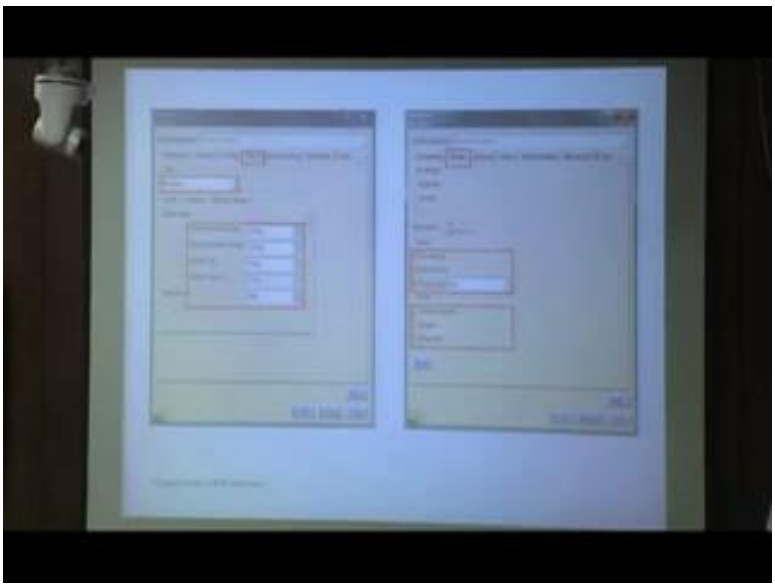

It will open this type of window, where this is the vision. Under vision, you can change it binocular vision, monocular vision, vision of both eyes, vision of single eye. So, we can select from this dropdown list. Similarly, we can also select the limits that we can create the binocular field of view for 100 degree or horizontal ambicular or horizontal monocular 100 degree horizontal binocular 190 degree, vertical top vertical bottom, so

all this angle we can set and based on that we can create our view field. Then we can display in different modes also from vision then we can go for display where we can mention different types of vision line of sight field of view pole. So, we will discuss one by one. So, we will first one let talking about this one, field of view.

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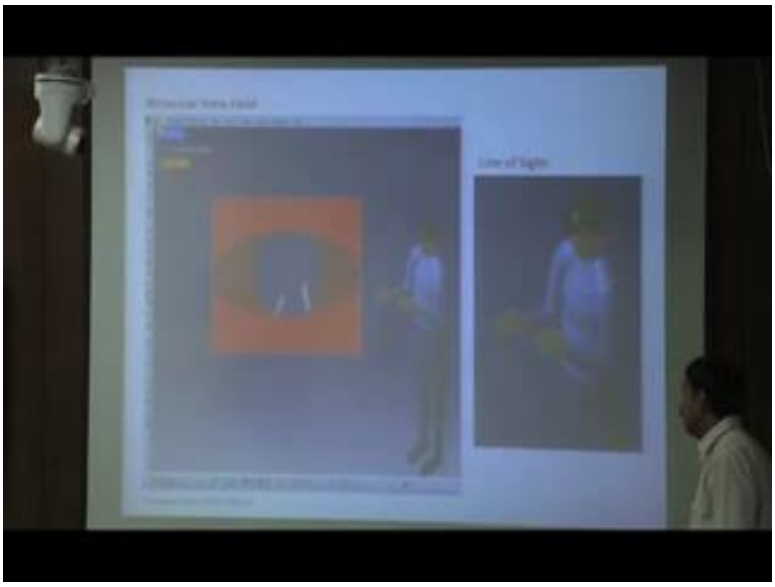

So, if you select field of view and then go for analysis then this type of field of view binocular field of view will be generated. So, while that individual is looking in front looking there at if this is that this is that is view area then actually how much area you can see we you can in two hands, so that is coming in a separate window, this known as binocular view field. So, similarly you can say monocular field of view also for left eye or right eye. If there is other objects also within this view field those view also be identified here. So, in this way with this tool we can check the vision or view field for that manikin.

Next, if you look at this one line of sight. So, we can create also line of sight. So, this type of line of sight is created with this line of sight we can identify where the particular manikin is looking at the particular point. So, the point can also be denoted can be identified with that line, this is called line of sight. We can with that line of sight we can identify the fixation point.

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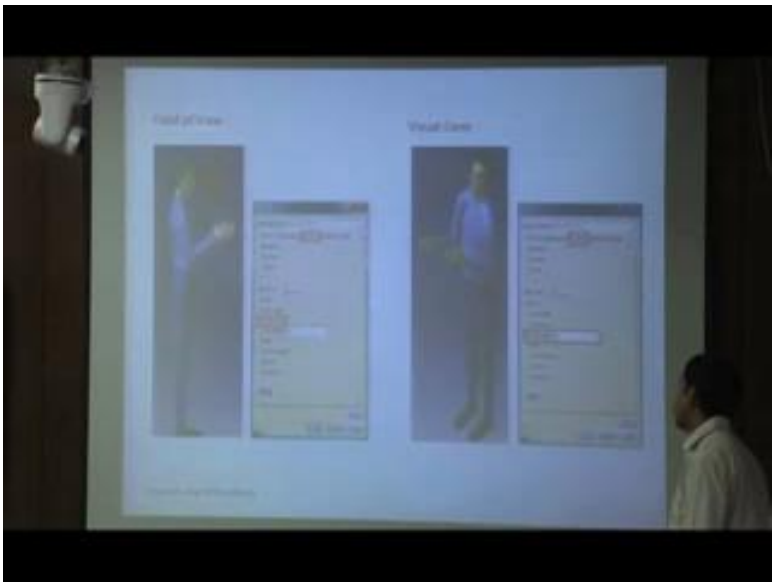

Similarly, we can go for view cone also. So, this is view cone; we can create view cone; view cone there are also different types of view cone also from this drop down menu, we can identify which type of view cone we want to create. You can change the angle, you can change the distance for what distance. So, from this height point, we can up to 100 centimetres forward direction, and we can want to create a angle of 30 degree or 15 degree accordingly we can define and we can create the view point with this menus. Similarly, field of view we can from display also you can select the field of view and we can create this type of field of view.

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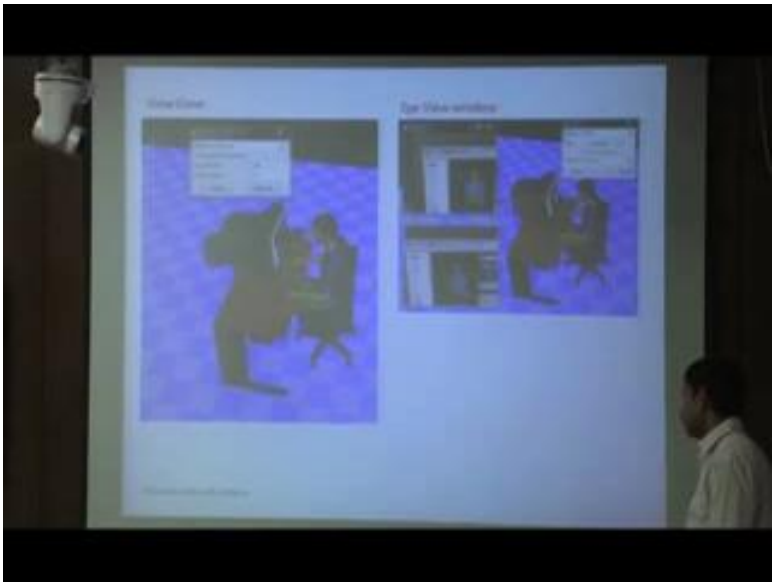

Now, if you use Jack software, in Jack software also there is vision module. In that software, how we can evaluate vision, we can select the particular human then display view cone, we can for both the eyes separate view cones are created, we can define the length and angle of that view cone and accordingly we can generate this type of view cone. And whether our object or whether our display within the view cone or not, we can check it.

Similarly, there are other tools known as eye view window. In eye view window, while that manikin is looking at the display, then we can see how much area or what objects are coming within this field of view. So, for this is the separate window, this is another separate window. So, this is showing for left eye, and this is for right eye. With left eye, the person can visualize this portion of the monitor; and with the right eye, he can show this portion of the monitor. So, in front of view, whatever objects are there while we are going for view field eye view of window creation then this type of windows are created where we can identified that which area for which objects that human manikin is looking at. So, in this way software to software there are different types of tools and menus; with this tools and menus, we can go for different types of vision analysis.

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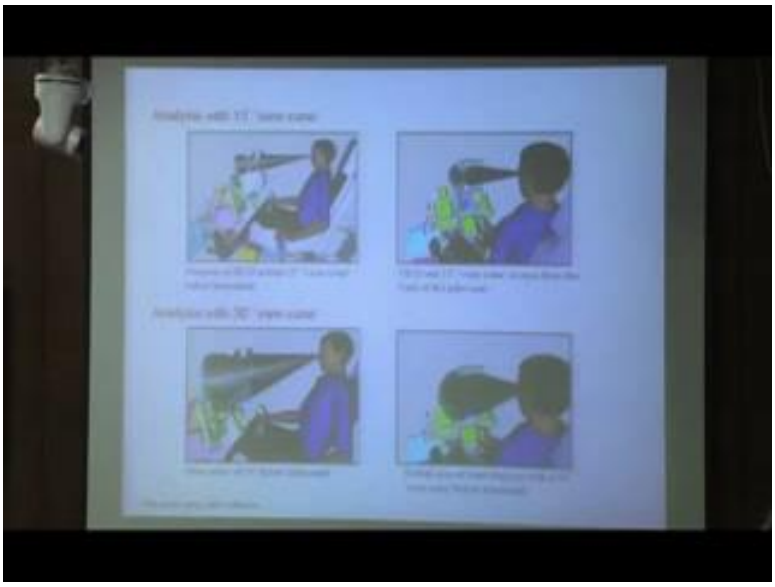

Now, here we are discussing taking example from one pop it evaluation in that pop it, whether the displays different types of displays positioned properly or not, we can taking this example and we can evaluate that one. So, regarding vision evaluation, so position

this type of digital human model say this is we can mention 58 percentile of 58 percentile of pilot whether pilot is positioned then we can create this type of 15 degree view cone. So, for initially what we are doing we are positioning we are keeping that neck angle 10 to 30 degree that is the normal human behaviour as we already mention in our earlier slide here as per this reference human neck is 10 to 30 degree forward field.

So, first we are giving this type of 10 to 15 degree forward tilted neck angle then we are creating eye view, view cone of 15 degree below horizontal eye level then we can find that this head of display is positioned correctly. So, pilot will be able to visualize the while his eye point eye is at desired eye point then this pilot can see the hidden display. This is side view, this is side view and this is the one perspective view. Similarly, if we create thirty degree view cone then, we find not only head of display some other displays are also being visible within the 30 degree angle same thing is also represented here. So, we are creating view cone, we can check the position of the display, which displays are coming within the view cone.

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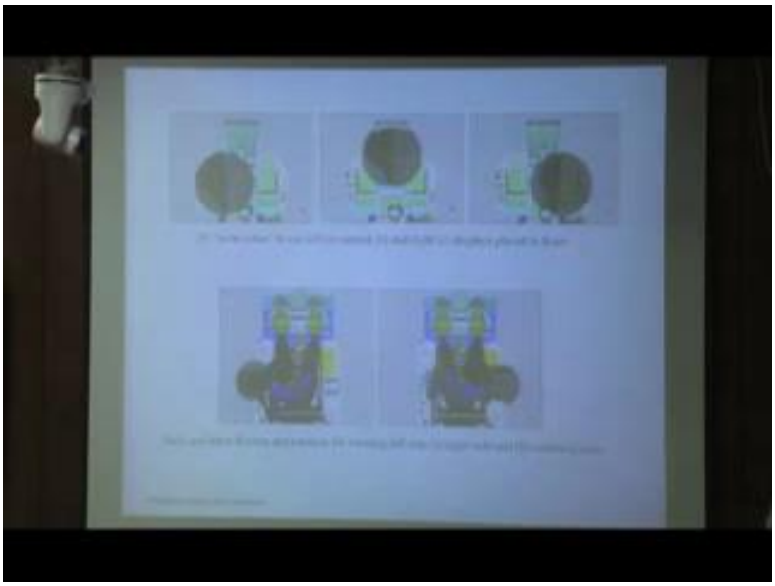

Now, if the driver moved his neck then the 30 degree view cone can be shifted like this, sorry left side or right direction. So, from this analysis, we can understand although that while the driver is looking in front straight ahead then you can visualize this display, but with little bit neck movement that neck angle also we can identified with little bit neck movement, you can visualize all other display. So, what should be the neck movement

range or visualize all the display we can clearly identified using digital human modeling software. Similarly, you have (Refer Time: 60:06) side control panels, what should be the neck angle while the person is looking at the side control panel that can that we can also identify, and we can calculate the neck angle also.

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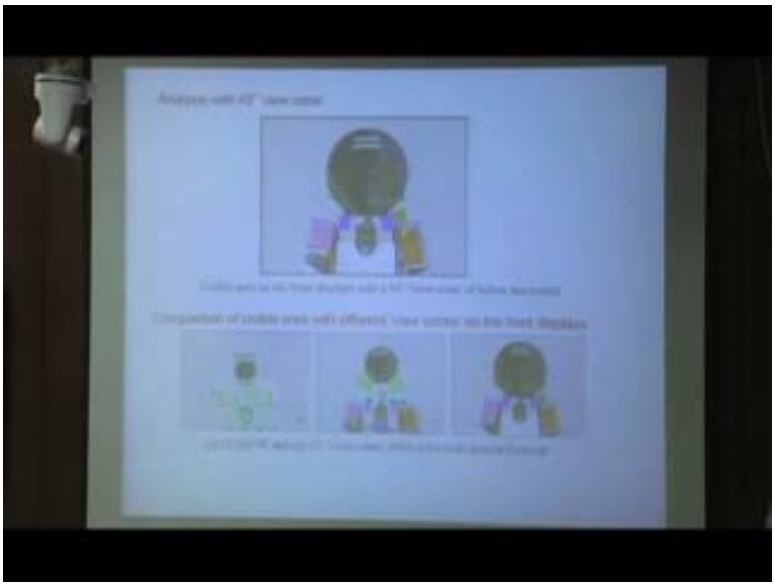

So, vision analysis not only helping to identify the position of different display within that view cone or view zone and it is also allowing the different to visualize different object or different viewing object what should be the angle of neck or movement of eye that also we can identify. Similarly, if bigger view cone is created 45 degree then most of the displays are covered. So, we can mention that in particular case with 45degree view cone most of the displays are visible, this one comparison starting from 15 degree, 30 degree, and 45degree. So, while we are increasing the area of view cone starting from 15 to 45degree then we can gradually see half reach area of the displays have view covered.

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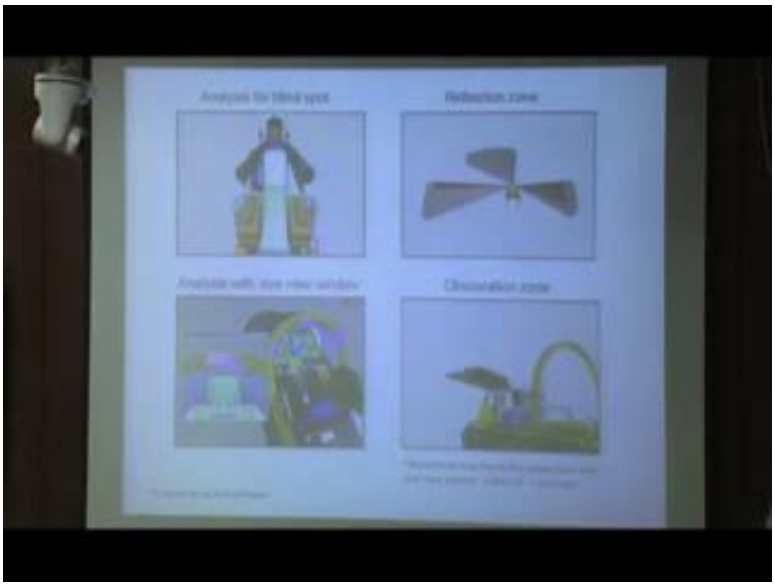

In most of this software, digital human modeling software, also this is this example is using jack software, but in other software also there is this types of digital this types of vision analysis tools; with that vision analysis tools we can go for not only view cone we can go for blank spot analysis. So, blind spot, what is blind spot we can study that one the blind spot are some area in our view field perhaps these are the zone where from if image is found on our retina in a particular area on that retina no image is actually visualized that area is called blind spot.

More elaborately on our retina, the back side of the eye ball on our retina there is some area where actually visual information is not recorded, because there is no visual receptor cells, optical nerves, blood vessels are passing through that area. So, inside our eye ball on the retina there is some area where fibre's and blood vessels are passing at that particular area, there is no visual receptor cells for that purpose image is not found there. So, where that image is not found that area is actually corresponding to this two black cones. So, if light wave or reflected the eye from object goes to this direction and falling on our retina. So, it will fall on the blind spot zone and image of that object will not be visualized. So, in this area we cannot position any display none of the display should be positioned in this zone.

So, pilots' basic purpose is he will look at the head of display, while he is fixing his eye on the head of display then these are the two zones, from this zones if light is come and

falling on the retina it is actually falling on the blind spot. And there is no visualization of image. For that purpose during design of this pop it, we should try to avoid keeping any display within this zone. So, in jack software, we can go for this type of blind spot evaluation.

Similarly, we can evaluate reflection zone. Reflection zone means we can also mention as the mirror view. So, through the mirror, if it is a vehicle or if it is a pupid from the vehicle or pupid there are different types of real viewing mirror, front viewing mirror. So, from that rear viewing mirror or viewing mirror we can visualize which area through the particular mirror we can visualize. So, in this case, if these are the mirrors then while pilot is looking at the mirror which area of the backside will be visible in with these three mirrors one, two and three - these three mirrors; with these three mirrors which area of the backside is visible to the pilot that is actually reflected here.

So, due to these three mirror position these are the area which is actually visible. So, this external field of view through the mirror is actually dedicated, this is known as reflection zone or mirror zone. Like CATIA software also in this case also we can evaluate eye view window. While pilot is looking at this display, then this is coming at the separate window this is a zone which is visualized to the pilot. So, this is coming at eye view window. So, while he is looking at head of display, so this top mirror and this portion is visualized, so that is shown in a separate window known as eye view window.

Similarly, this software not only jack in other softwares also software have the capability to show obscuration zone. Due to this structure or this canopy bow, due to this canopy bow or this mirror this is the cope area actually will be obscured. While the pilot is looking then due to existence of this canopy bow, this is the area where pilot cannot see, so that can also be evaluated with obscuration zone field.

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Here is another example of obscuration zone. So, while pilot is using this joystick and manipulating the joystick, during the navigation there is one display; due to location of this joystick the pilot cannot see this area, this is obscured zone. So, this type of obscured area with this shredded zone is actually we can check using this type of obscuration zone tool. This obscuration zone tool is also available in this type of software.

Then another example, due to existence of this type of structure, beyond that structure this zone actually not visible to this human. So, we can create this type of obscuration zone using obscuration zone tool. So, in most of the digital human modeling software, jack, samie, ramsis then delmia, we can go for different types of vision analysis tool, with that vision analysis tool, we can create view cone, eye view window obscuration zone reflection zone. And ultimately we can check that whatever facility that may be vehicle that may be aircraft field that may be any other workstation that for any other facility that whether vision or that intended audience are the intended targeted population is sufficient or not, whether they can do their routine activities related to vision related task, so that we can check with this various tools of those softwares.

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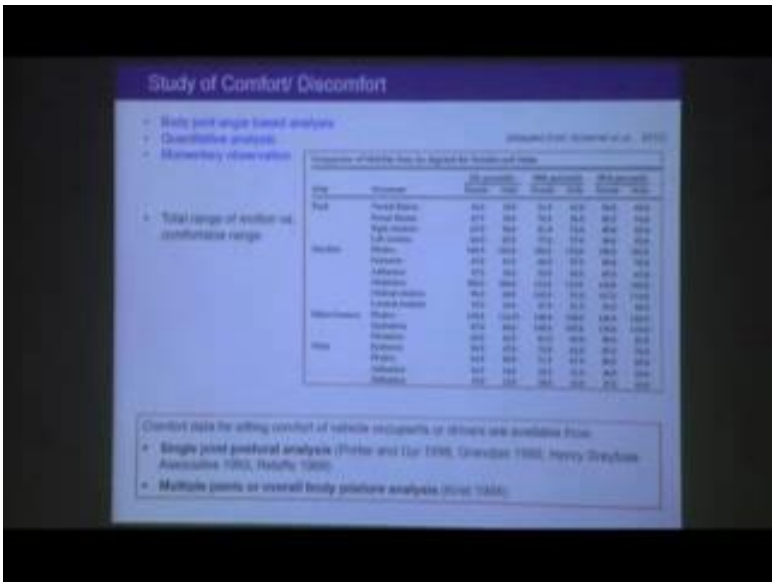

Next, we are going to discuss about comfort and discomfort. Now, in digital human modeling software, comfort is evaluated based on the body joint angle. And thus it is the quantitative analysis, but the observation is momentum in nature. For a particular posture, we can evaluate for that particular posture, for that particular moment based on the body joint angle, we can identify whether that posture is comfortable or not. But what is the effect of prolong duration of a particular posture, while there is sustained posture or constrained movement of human body that scenario in that case how is the comfort we cannot evaluate with this type of physical digital human modeling.

The whole evaluation is based on only body joint angle. So, effect of time is not coming into picture. Now, while we are discussing about comfort, discomfort in digital human modeling software as it is dependent on body joint angle. So, we are just referring our earlier module while it was mentioned that we need comfort database and range of motion data. So, generally for different body joints neck, shoulder, elbow, so in this different body joints there is different degree of freedom mental flexion, torsional flexion. So, based on extension adduction abduction different types of body parts movements are there. And we can also collect data; based on that data we can collect 5 percentile, 15 percentile, 95 percentile.

So, for a particular target population or intended population, we can collect for any particular body joints a range of motion data. After collecting the data for both male and

female, we can calculate different percentile values. As it is mentioned here for name joint there are different degree of freedom and in different degree of freedom there are different percentile values, so that is calculated and tabulated.

Now, this is data of range of motion, but throughout the whole range of motion or we cannot work comfortably. So, for examples, if we consider the shoulder joint and this is flexion and extension, so in this case, this hand can move from this position to up to this position. But the entire range of motion is not comfortable. Out of this, this is the entire range of motion for this particular shoulder joint right in this particular degree of freedom where there is flexion and extension. And out of this complete range of motion, based on the work activity, what type of work we are doing whether seated work or standing work or based on the nature of the work, we can define.

Say for example, this is the standing work probably the mid range of the shoulder movement. So, this range may be comfortable. So, not the entirely; out of that entire a particular range of motion that is defined as the comfort zone. So, this comfort database one is range of motion data; out of that range of motion a particular range which is defined as the comfort zone that data is important. While we have that data then we incorporate that data in digital human modeling software while we are developing that manikin and as per that body joint angle we can analysis comfort.

Now, different comfort database are available for driver or occupant packaging. So, we find that these are the references for single joint posture analysis. So, these are the reference; from these reference, we can evaluate for a particular body joint whether it is shoulder joint or elbow joint or wrist joint whether that joint is within comfort range or not. But there is also multiple joint or coheral body posture analysis from Krist 1994. So, based on various different joints in our body, we can calculate the whether the posture is comfortable or not. So, this type of databases are available we can used our databases for our comfort evaluation purpose.

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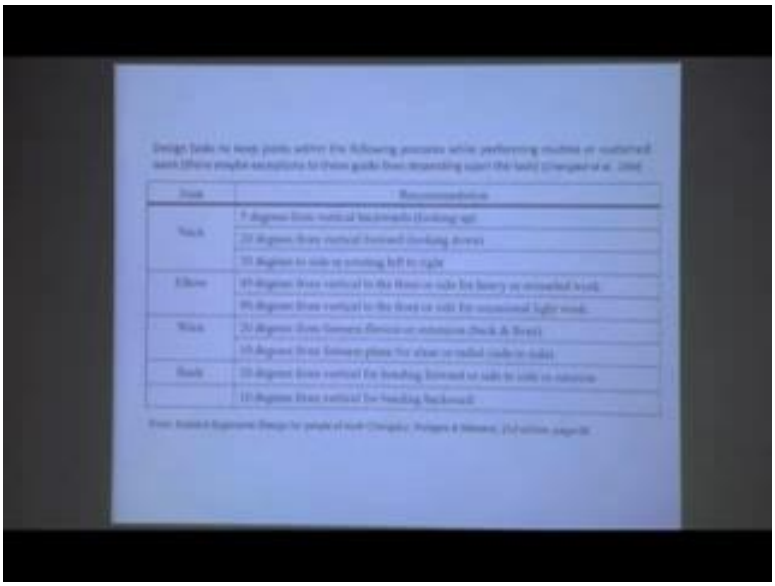

Now, if you see this recommended limit design task, we need to design task to keep joints within the following limits. If you prefer general purpose work, like performing routine or sustained work, in this case neck angle should be within this range, elbow angle should be 45degree from vertical into the front or side or heavy extended work; 90 degree from the vertical to the front or side for occasional work. So, in this way different types of comfort range of body joint angle is defined and those based on those data we can evaluate comfort.

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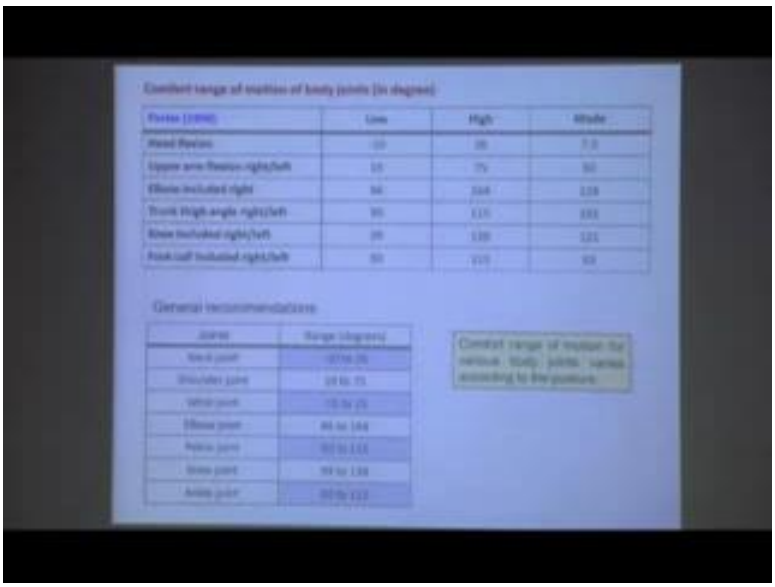

Next, for diver or occupant, Porter, 1998 define different body joint angles the range of comfort, comfort range of that body joint. For head flexion, he mentioned as it is starting from lower range is minus 10, and high is 26. So, if we considered that head flexion using within comfort zone then it should be within minus 10 degree to 26 and mode is 7 degree. Similarly, knee included left and right, it is starting from 99 degrees low and upper end is 138 degree and mode is 121 degree. So, in this from different databases, so we can use this type of body joint angle data for comfort analysis this is the comfort range of motion for this body joints as proposed by Porter 1998. Similarly, for general purpose for automotive industry for driving posture, we can use these types of body joint angles.

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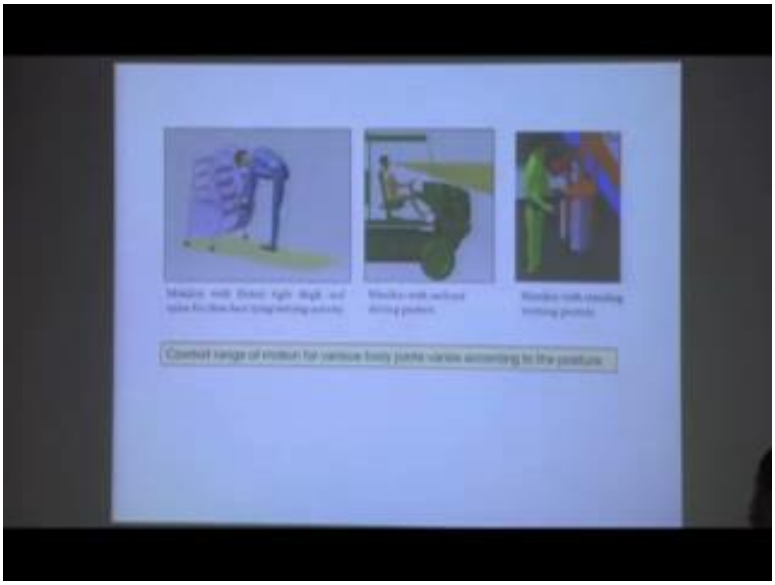

Now, this is important. The comfort database for driving posture is not applicable for while we are evaluating any task in standing posture. So, we have to identify appropriate comfort database as per our requirement. So, the database which is applicable for automobile or digital design that database or diving comfort analysis that driving comfort data is not applicable for evaluation of industrial work place where standing work or bending work is involved. Where different types of activities are going on out of those activities various types of posture will be found, those posture cannot be evaluated based on the comfort database defined for vehicle for automobile.

So, for different types of postures, so this is very important comfort range of motion for various body joint varies according to the posture. And for particular posture, particular type of work, we have to identified the comfort database. Read that comfort database is not available then we have to develop the comfort database. Accordingly, we can evaluate the posture using digital human modeling software.

Without that comfort data it is not possible. So, here few examples are given. So, for someone is doing some activity like his manikin is tying his shoe lass, this type of forward bending posture is there and leg only, he is standing on one leg and another leg is on the this or at this place. Similarly in this case, it is the driving posture where a driver is driving. So, these postures are completely different. This is industrial workplace where workers are working and that here the manikin is standing position. So, if I want to evaluate the comfort for the various body joints for these three cases the database required for comfort evaluation obviously must different. So, one database completely applicable for another, because of particular type of work you have to define what is the comfort range.

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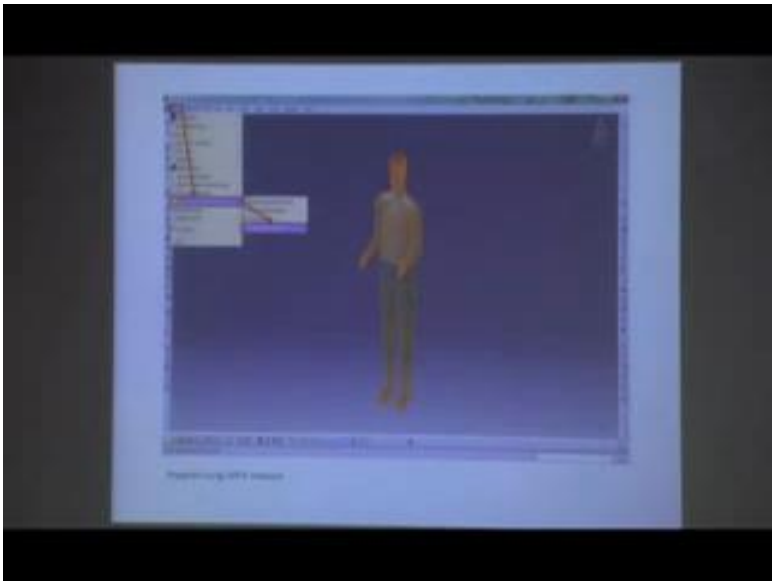

Now, if this comfort evaluation, we will explain with example of various software. So, first we are taking the example of CATIA software, while we are using CATIA software for comfort evaluation for various body joints then how we should proceed. So, there is

posture you will find ergonomic design analysis under that we will find posture analysis, human posture analysis. So, you have to click on that one then this window will open.

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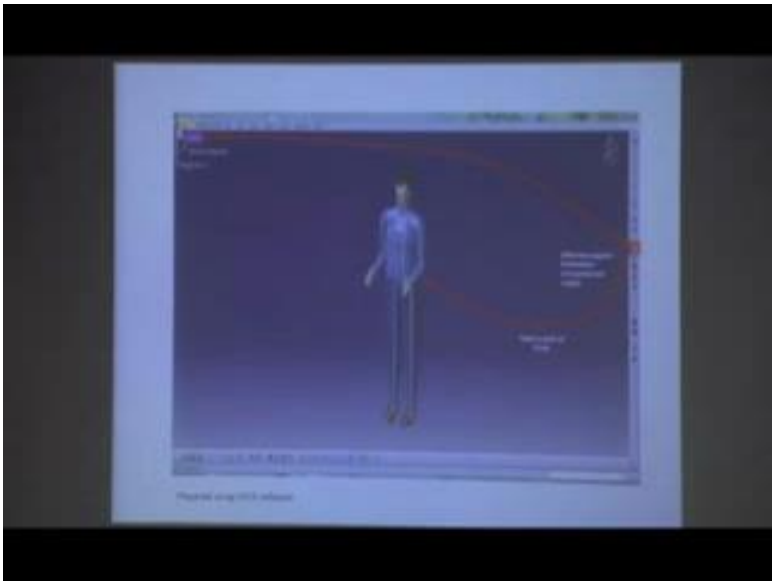

From that window, you will find this type of tool it is written edits the angular limitation and preferred angle. So, you have that opportunity for a particular body joint, if you consider this elbow joint the range of motion complete range of motion or the total angular limits, we can modify, because editing option is there. For that purpose what we need to do we need to do first we have to select a particular body part body segment. So, assume we are selecting this lower arm and this particular elbow joint.

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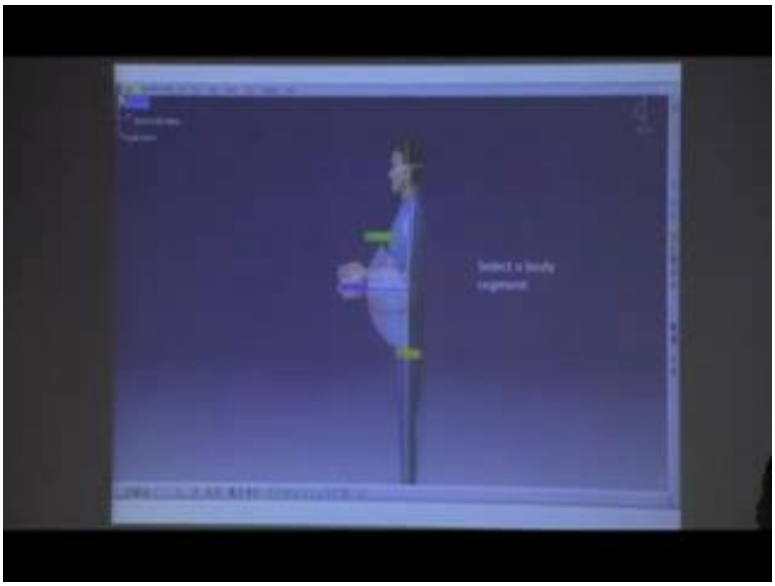

So, while we are selecting that elbow joint then we will find this type of range of motion for this elbow joint. So, starting from 0 degree and it is going up to 140 degree. Now, this is the complete range of motion instead of for this particular elbow joint, it can moves from 0 degree to 140 degrees, this is the comfort range, and this is the total range of motion.

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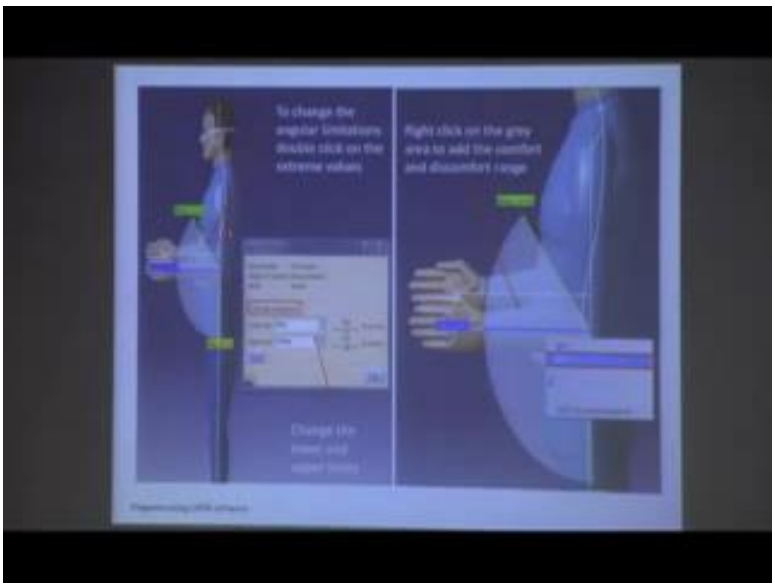

Now, out of the total range of motion, now what we can do, we can kill the limit. Now from this point we can this limit here we can edit this limit. So, we can increase or

decrease as for our comfort range database. Now, how to change? So, there is this type of angular limitation window from that window you have selected the particular body parts and now activate manipulation. So, you can manipulate. So, lower limit you can set 0 to 140 degree it is already set, now you can as per your requirement you can modify this one. If you have for this particular body joint, if you have that data that what should be the range of motion for this particular body joint for your intended population accordingly you can set the limit.

So, this is what range of motion. While that range of motion data is set then you are going for defining the comfort zone, out of the complete range of motion now you are going to define the comfort zone. For that purpose, you have to right click on this one, you will find the add option. And also for any particular joint as per the degree of freedom, you have to find out that; for which degree of freedom you are going for flexion extension or adduction abduction or rotation for which degree of freedom you are going to modify the angular limit and also you are going for evaluating the comfort. So, from this flexion extension this is the complete range of motion in that complete range of motion now we are adding the comfort zone.

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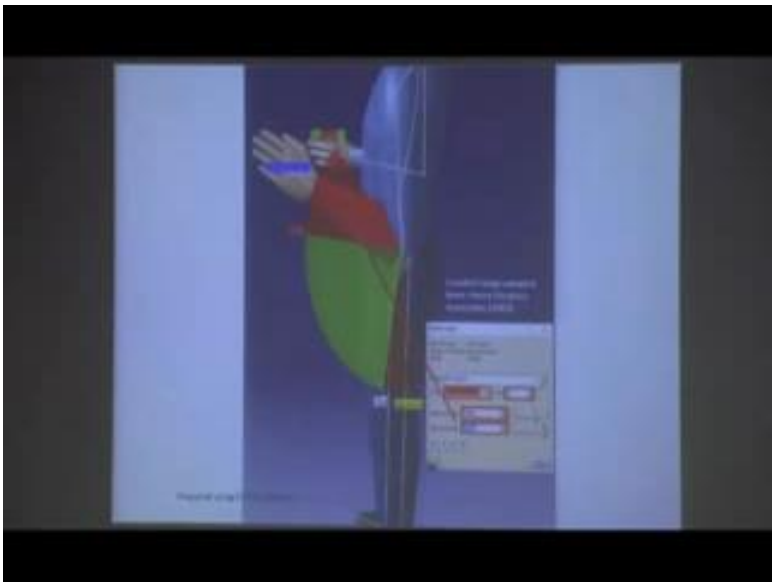

So, first we are dividing based on this reference data (Refer Time: 81:16) 2002, based on that data the whole comfort range whole range of motion we are dividing in three zones. So, first we are dividing from 0 degree to 15 degree this is not comfort. So, first zone, we

are defining as per the database 0 to 15 degree is not comfort zone. So, we are putting colour red for that purpose and we are defining the angle starting from 0 to 15 degree.

Next, we are adding one more; next zone which is from 5 degree to 100 degree, this range is the comfortable zone or the comfort zone. So, this is the second zone that is denoting with we are denoting with green colour tool indicate that this is the comfort zone. Then we are moving for third. Now we are moving for third one. Again we are here we are defining red colour starting from 100 degree to 140 degree within this zone within this range of motion, again what is not comfortable.

So, the first joint this is not comfortable zone, this is also not comfortable; the middle range of motion starting from 5 degree to 140 degree within this range it is comfortable, for what withstanding working or some other work activities. So, in this way we have to define. But after defining now the complete range of motion has been divided into three zones; out of these three zones this middle portion is defined as the comfort zone.

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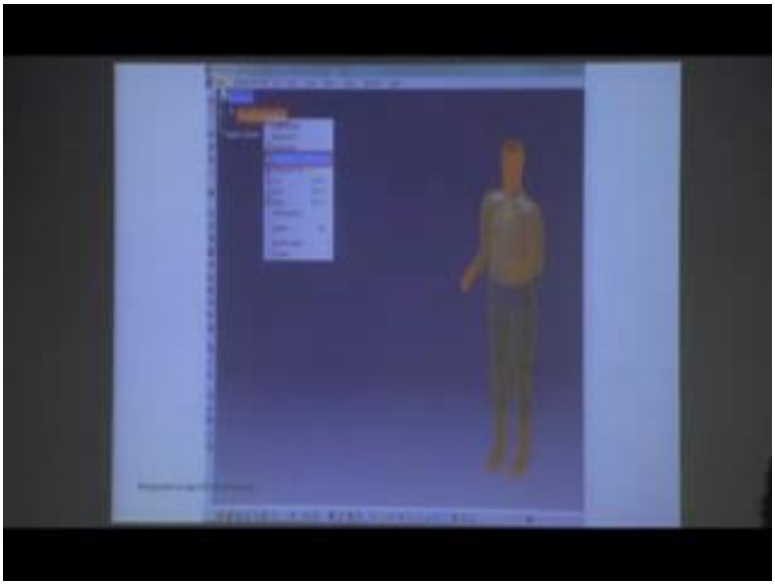

Next, while after the defining the comfort zone, body joint individual body segment will not be highlighted within a particular colour. Although we have defined the colour red and green; for to highlight the body segment with the specific colour, we will have to go for next from the manikin properties. While we are clicking on properties, this property window will open.

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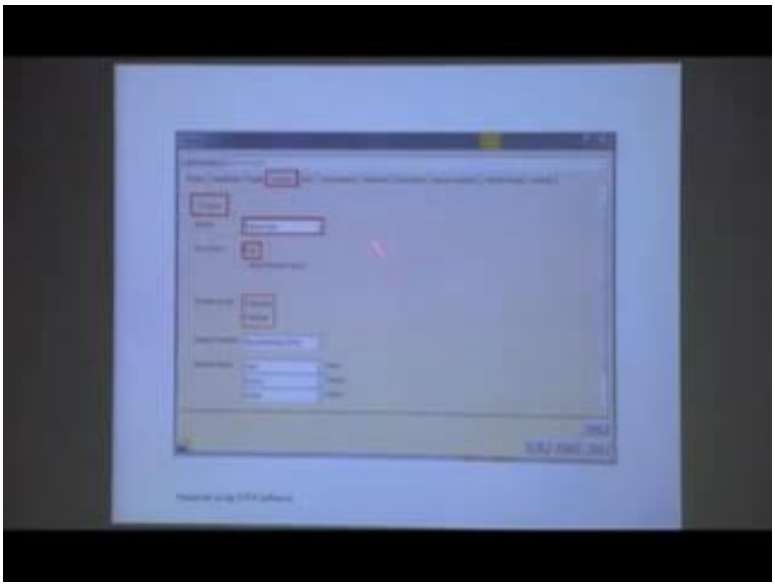

While this property window is opening from that window, we are going for this tab colouring. Under that colouring tab, first we are clicking on activate, means colouring should be activated. Then what is type of analysis postural code again you can from drop down menu you can change postural code reverse code, you can go for that one, then show colour for which segment, for all the body segments. So, now element of colour segments and surface both show, for elements and surface and show all the colours show also in red colour and green colour. And here show the colour for both segments and

surface. Now, for which particular for which degree of freedom; obviously, we are now analyzing with flexion and extension. This flexion and extension we are now analyzing.

Now after activating this while it is activated for these segments then if we click on open then we find this type of colour. Now, if we manipulate this particular body with body joints means elbow joints if we move the hand up and down along this particular degree of freedom, then while hand is at this position then hand colour is this, lower arm is denoted with red colour. While the hand is moving in this middle portion middle zone that is comfort zone now the colour of the lower arm has been converted to green colour. Now if we move the hand upward in this direction then colour of the hand now you can see from this portion because now lower arm colour has been change to red colour.

So, first we have to define the angular limit; then in that angular limit we have to define the comfort zone. While the comfort zone is defined then we have to activate the colouring option, while colouring option is activated after that whenever using manipulate the particular body joints as per the degree of freedom then accordingly the colour will be shown on the particular body segment.

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So, this was whatever we discussed it was this example was from CATIA software, but for other software for example, next one this is from jack software. So, in jack software, how this comfort analysis is done based on body joint angle. In this case, if we select the particular manikin and go for comfort analysis, then it gives this type of colour coding.

But various body parts, it shows the angular value in degree 15 degree, 8.2 degree and if that is within comfort range then it shows with as per this say in this particular case analysis has been done as per the (Refer Time: 86:27) seating method.

And based on that method for upper arm if the flexion is 8.2 this is indicated with green colour means this is in comfort zone, but the left arm is not in comfort zone because that is indicated in yellow colour. So, with colour coding option, we can understand that which body parts is within comfort range of motion and which body parts out of that range. So, that is actually shown from this table and you can find out the difference in colour in different body segment.

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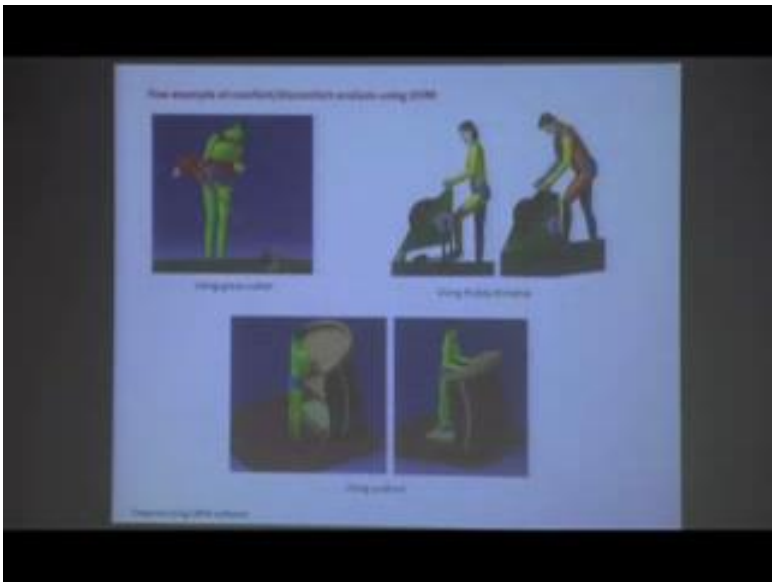

Next, few other examples; so in this examples, already comfort joints or comfort range of motion for different body joints have already been defined. After defining comfort range of motion for different body joints, we are going for evaluating various types of products and workstation. During that time say in this case while that manikin is using grass cutter or handling grass cutter machine, during grass cutter machine what is happening this few body parts indicated with red colour. Mean those body parts this (Refer Time: 87:46) portion and lower back those portion is indicated with red colour mean these body segments are beyond the comfort zone for comfort range.

Similarly, in other example, here while this we are evaluating paddy thresher in virtual environment, and we have defined the body joint angles comfort as per the comfort

database. Then we can find this fifth percentile female it is showing in this body parts in yellow colour, but body parts in green colour mean this is within in comfort range, but this body parts are beyond comfort range, because they need to bend forward. But in case of 95 percentile male, the situation is worst because these body parts again indicated with the next colour coding that is orange. So, while it is there is no discomfort then blue colour while there is discomfort then it is indicated first with yellow, then if you can define with other colours also if it is beyond. If it is severe discomfort then it will be shown in some other colour lighter orange. So, in this way with colour coding option, we can evaluate our particular product or workstation while we are making a simulation where manikin is performing some task during that task has various body segments using comfort data we can evaluate comfort using colour coding.

Similarly, in this example, while this person is using this podium as this is the fifth percentile manikin; and standing on the ground this is height of the surface of the podium is actually not comfortable for this person. His lower arm is actually indicated with red colour. But if we increase the height if we use this type of say some extended structure, if we use this structure then he can stand on that structure, so that they can easily now his hand posture has been changed. Initially hand posture was like that like this type of accurate curvature was there, but now while the fifth percentile manikin is kept on this type of platform. Then what is happening, now that person can stand on this one, his height has been now vertical position has been changed, and now elbow joint elbow joint also be changed, now colour is indicated with green. So, in this way using colour coding, we can evaluate our product of facility.

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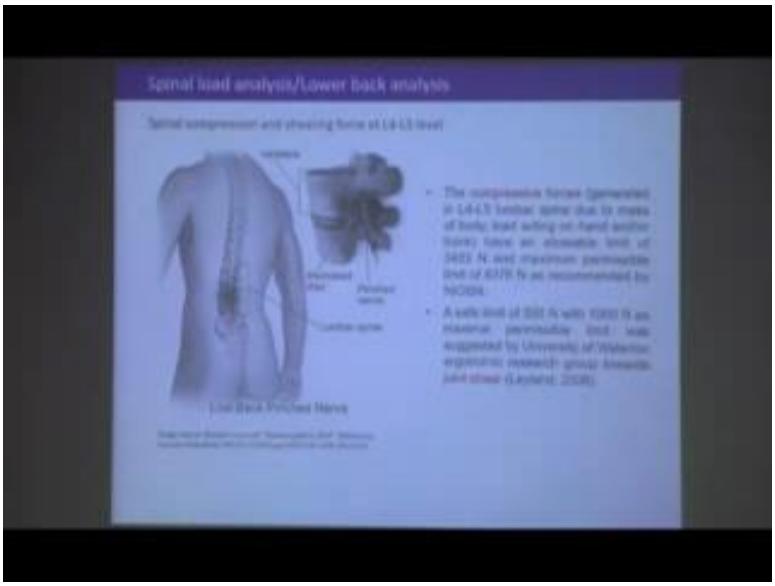

After discussing about comfort evaluation, it is based on comfort database for various body joints and also indicating colour coding using colour coding. Now, we are moving towards spinal load and lower back analysis. So, this is also another feature for most of the digital human modeling software, where we can evaluate low back analysis or spinal load analysis.

In our earlier module, we discussed that is our vertebral column in vertebral column different regions are there. So, we mention like thoracic cervical portion, then thoracic then lumbar portion, (Refer Time: 91:34), so different regions and zones we defined. So, this particular portion is known as lumbar zone. So, there are total five bones in lumbar segment. So, out of those five lumbar vertebrae between L 4 and L 5, so also we have already discussed the this vertebrae through this vertebrae or spinal cord is passing by. And in between two vertebrae, we find this type of cartilaginous sparing material which is known as inter vertical disc. So, in between two vertebrae we find this type of inter vertebral disc.

So this is one vertebras, this is another vertebras. So, in this way, all the vertebras are arranged; and between these two vertebrae, we are finding this type of cartilaginous material that is known as inter vertebral disc. During our movement for forward bending or lateral bending or back leaning that time these inter vertebral disc get compressed due

to this structure; sometimes there is compressive force on this inter vertebral disc sometimes there is shearing force. So, we discussed in our earlier modules.

So, now, with digital human modeling software, we can evaluate how much is the compressive force or shearing force in inter vertebral disc while some particular task is being performed by the manikin and particular posture is adopted. So, generally that analysis is done at the level of L 4 and L 5 mean lumber segment 4 and 5 in between these two lumber segment the inter vertebrates at that region we measure the inter vertebral disc pressure. So, disc pressure is as we mention two types' compressive forces are here and also shearing force is also there.

The compressive force generated in L 4-L 5 lumbers point due to mass of the body or load acting on hand or any other body parts have an allowable limit of 3433 Newton and this is the allowable limit means safe limit. If the compressive force generated at L 4-L 5 lumbar point if it is less than 3433 Newton then it is within safe limit. But if and the maximum permissible limit is 6376 Newton, 6376 Newton that is the maximum permissible limit, it is recommended by NIOSH. So, this is the information regarding compressive force.

So, with digital human modeling software, we will measure that what is the compressive force at L 4–L 5 region, and if we find that force is less than 3433 then we will find there is no problem, this is that within safe limit. But it should and it obvious should not go beyond 6376 Newton; if it goes beyond that then we need to modify the task we need to modify the task, so that posture will be changed and the person will be able to adopt different posture where there is less final compression. So, this is compressive force.

Next, another type of force is also acting there that is shearing force. Compressive force means up down vertical pressure; and shearing force means forward backward or sidewise. Lateral shearing that may be forward backward also in lateral direction. So, a safe limit of 500 Newton with 1000 Newton has maximum permissible limit was suggested by University of Waterloo, Ergonomic Research Group towards joint shear. So, if we allow this reference, then we will find for shearing force its limit is safe limit is 500 Newton and it can goes maximum 1000 Newton.

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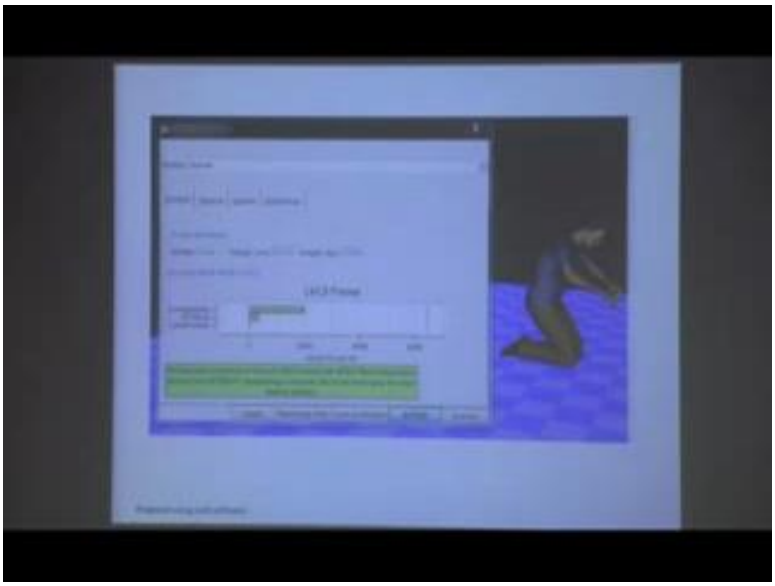

Now, how we can evaluate that for evaluation purpose we can use different software now we are giving the example from jack software in jack software how we can do that one. So, there is one tool called lower back analysis. In lower back analysis tool, first we can give the particular working posture to that manikin and during that particular working posture. Now, we want to measure what is the L 4 L 5 spinal compression and shearing force. So, while we are giving the particular posture; at the same time, what we can do we can also there is another tab that is called load dynamics. We can also define the loads that some loads is for example, 5 kg loads is acting on shoulder or some load is on hand. So, those load we can also define loads and poets after defining those where those options are there.

Then we can go for analyzing while we are activating this one then it is giving this type of data. So, in this case height is there, body weight, it is already selected from the manikin. Now L 4-L 5 forces, one is compressive force. So, that data is showing here then another is anterior posterior shear anterior posterior shear that is also showing and next one is lateral shear that is almost negligible. So, if you find here. So, recommend as per the recommendation limit whether this within safe limit or not that is also come at this particular space. So, where it is written the low back compression force here it is calculated as compression force. It is 1964 Newton is below NOISH, back compression action limit that is 3400 Newton thus it is representing that this is there is nominal least

of low back injury, based on the compression force whose which is indicating the value of value of 1964 Newton that is within the safe limit.

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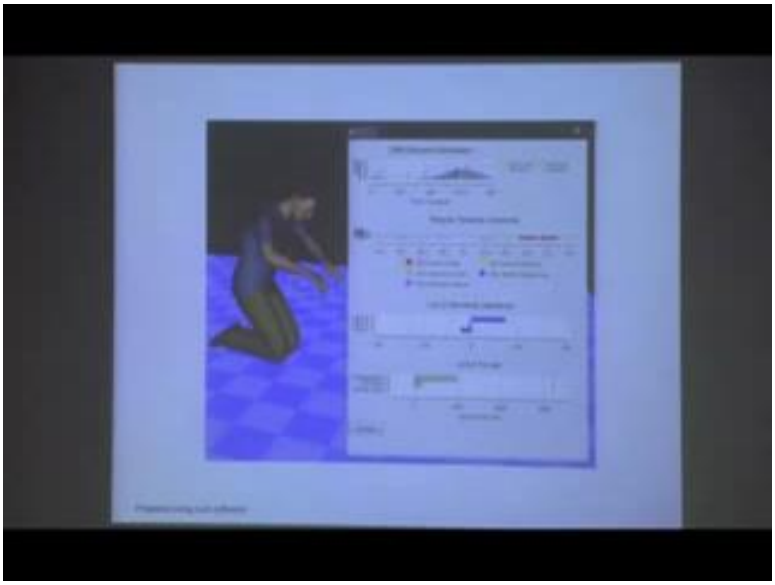

Now, remain we can plot graph for other variables also like DHM movement distribution. So, this is polar histogram for that purpose, moment at various body joints that is also shown here. Muscle tension for few selected muscles it is also showing how much muscle tension may be while that person is adopting this type of posture in a various muscles what may be the muscle tension that is also reflected in graphical form and also it is showing as it is shown in earlier case also. L 4 L 5 movements, it is showing an L 4 L 5 forces compressive force or shearing force that is also indicated. So, we can from this analysis we can get this type of various analysis analyses moments forces muscle tension and distribution of moments. So, this example was from jack software and how using tools of jack software how we can evaluate lower back.

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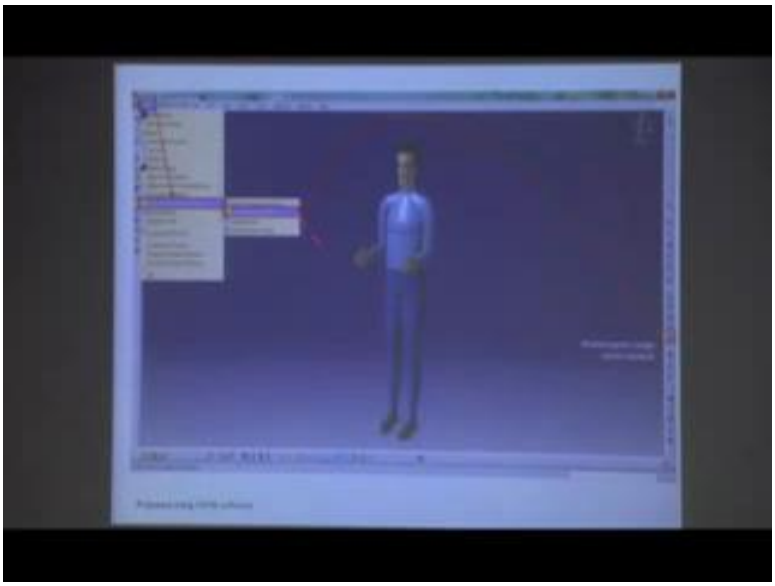

Now, the same thing while we are evaluating low back or spinal compression or shearing force using other software like CATIA software. In CATIA software, this type of human modeling is there how that analysis is done. So, first we have to go to start then there will find ergonomic design analysis under that we will go for human activity analysis. So, here you have two moves for this particular tab that is human activity analysis. When you go for human activity analysis window, then this type of window will open or you will find biomechanics single action analysis. So, you have to click on this tool that is biomechanics single action analysis while this tool is selected.

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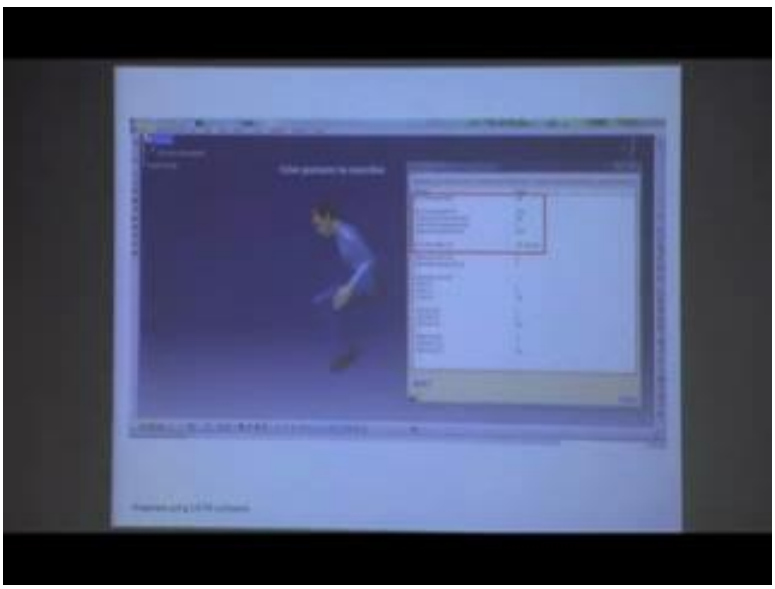

Then you have to give the particular manikin posture that working posture and during that working posture. Now, this window will open that how is the forces at L 4 L 5 level, L 4 L 5 moment, L 4 L 5 compression force, L 4 L 5 shearing force. So, the value is indicated here. So, you have to select that manikin you have to be specific posture after that while you are clicking on this particular tool that is single biomechanics single action analysis. Then we will get this type of scores for L 4 L 5 compression force, L 4 L 5 moment that L 4 L 5 segments then compressive force as well as shearing force. So, what we discussed still now that is low back analysis using to define software

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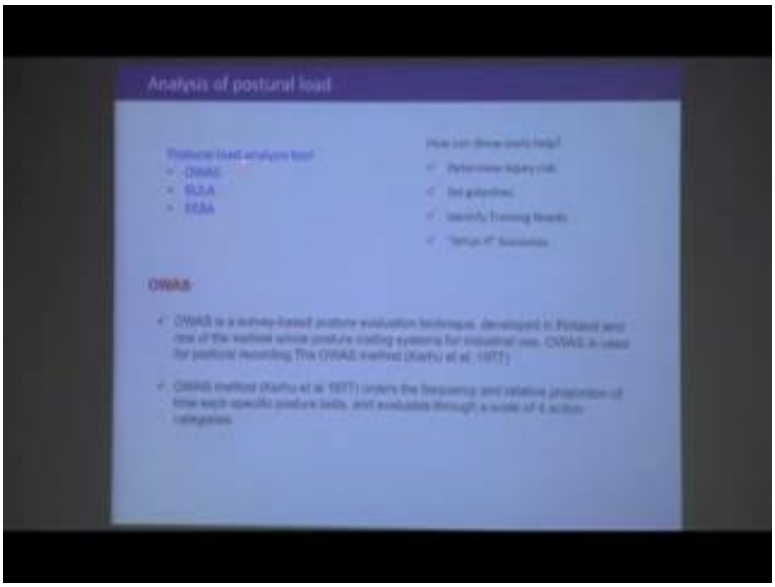

Now, we are moving to next type of analysis that is called posture load analysis. In different digital human modeling software, we find this types of tools OWAS, RULA, REBA, OWAS these are the posture analysis tool for already these are well established ergonomic evaluation tool for evaluation of posture. Now, all these tools may not be incorporated in all the softwares software to software is hidden. For example, in jack software, OWAS, RULA, included, but in case of CATIA then only their RULA is OWAS is incorporated. So, this is the way software to software is varies.

Now, these tools are very important because with this ergonomic posture evaluation tool we can determine injury risk how to set priority to modification of that particular posture. First, you need to modify the task you have to set priority to modify the task and accordingly modifying the posture identifying whether need of technique is there or not.

Then what is scenario if we modify the work space or task requirements or pattern of even body pass movement then whether there is any change in the score of this postural evaluation tool.

So, first tool which we are going to evaluate that is OWAS - O W A S - the full form is overflow working posture analysis system. So, what working posture analysis system is a survey based posture evaluation technique it was developed in Finland and it was proposed by it was first designed by Karthu et al 1977, OWAS method orders the frequency and relative proportion of time each specific posture lasts and evaluates through a scale of four action categories. So, in OWAS techniques, there are four action categories. First you have to evaluate the posture, if we find what is the as per this OWAS technique, what is that score. And based on that score we can go for recommendation. There are four action categories; we have to based on the score we have to select which action category will be implemented in that particular posture.

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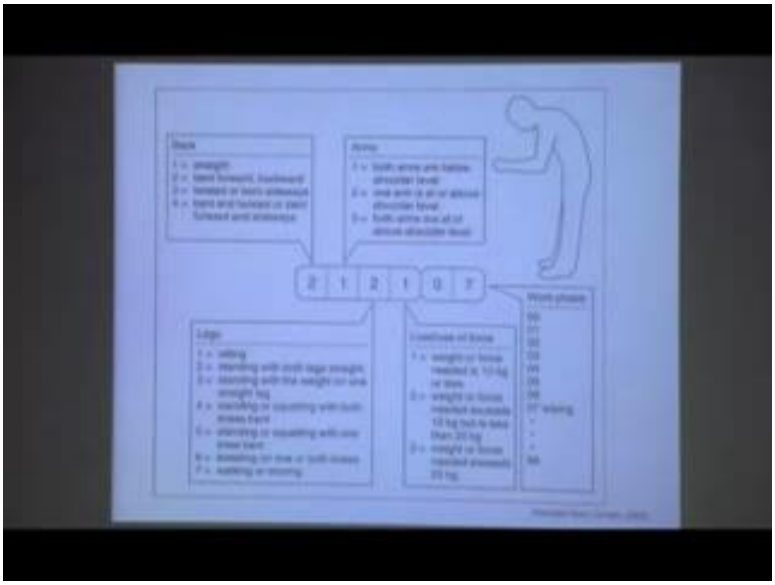

Now, we should must know about the must have basic understanding of OWAS tool then only we will be able to use that for out postural load evaluation using our digital human modeling software. So, that if you understand the theoretical background then we will find in OWAS tool what is done there are four body, these are the three body segments – back, arm and legs; based on these three body posture body orientation of this three body segments actually OWAS evaluation is performed.

So, first there is these are the scores different types of back or tongue posture if tongue is straighter than you have to put one if trunk is bent forward for this particular case if we take this particular posture then we will find bent forward, posture is bent forward. So, out of this 1, 2, 3, 4 - four types of scores are there out of this four scores, we are identifying for this bent posture 2 is the score. Similarly, for arms both arms are at elbow level. So, different scores are there for different types of posture of arm; out of that in this case we are identifying it are applicable here is one. So, both arms are below shoulder level. So, you are putting one.

Similarly for legs for legs there are total seven postures may be there. So, there are categorize the leg posture (Refer Time: 106:15) et al, they categorized in seven postures of leg. Out of those seven postures, we have to identify which one is applicable here. In this case, we find it is applicable two, two means standing with both legs stage. So, in this case, the person is standing on both legs. So, value is score is 2. So, back score is 2, arm score is 1, and leg score is 2; with that we are adding another for load use, load or use of force. So, if there also it is defined as there may be three scores 1, 2 and 3 when it is 1 weight or force needed is 10 kg or less.

While the force is 10 kg or less then we are giving score of one. While weight or force needed exceed the amount of force, which is required for that particular task if it exists 10 kg, but it is less than 20 kg at that scenario score is 2. Then three weight or force needed exceed 20 kg. So, these three types of scores are available one while the weight or force is 10 kg or less then value is 1; while it is 10 to 20 kg then 2; while the weight or force requirement is 20 kg or more then that is 3. So, in this way, we can identify which one is applicable here. So, here it is applicable 1.

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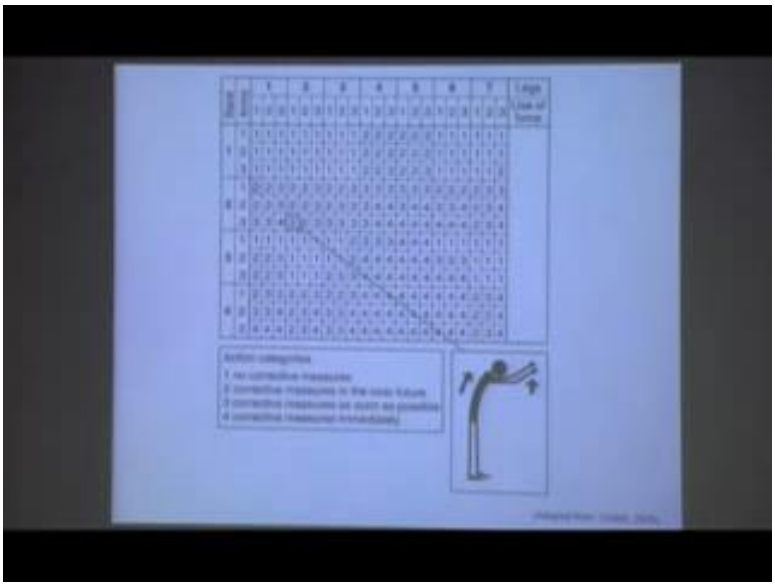

Then based on all this thing there is another chart. If we go to the next slide, then we will find from this chart. So, already we know for back score, it is 2 then we are moving to arm score from back score, if you see this one back score is 2, again is that arm score is 1. So, first, from this table, we have to from back score this is the back score 2 then arm score 1 then leg score again 2. After that so back score may is four types in this particular case 2 is applicable; then against two arm score may be 1, 2, 3, here one is applicable. While arm score is one against the leg score may be total seven types of legs score available out of that here it is applicable 2. While leg score is also identified then we will ultimately find out the point this two that is the posture the final score. So, final score is coming two based on only on the posture.

In posture back arm and leg. So, score is coming two. So, action categorize is based on this final score is of four types. So, in OWAS technique there are four action categories for the grand score. So one no corrective measures are required corrective; if the grand score is two then corrective measure is required near future; if grand score is three, then corrective measures is required as soon as possible; otherwise, if grand score is four then corrective measures required immediately. So, in this case, all grand score is after putting all this thing for back, arm and leg then it is coming to final score 2. A final score is 2, then in this particular example it is coming that corrective action or corrective measures is required in near future, so that is not that much problematic.

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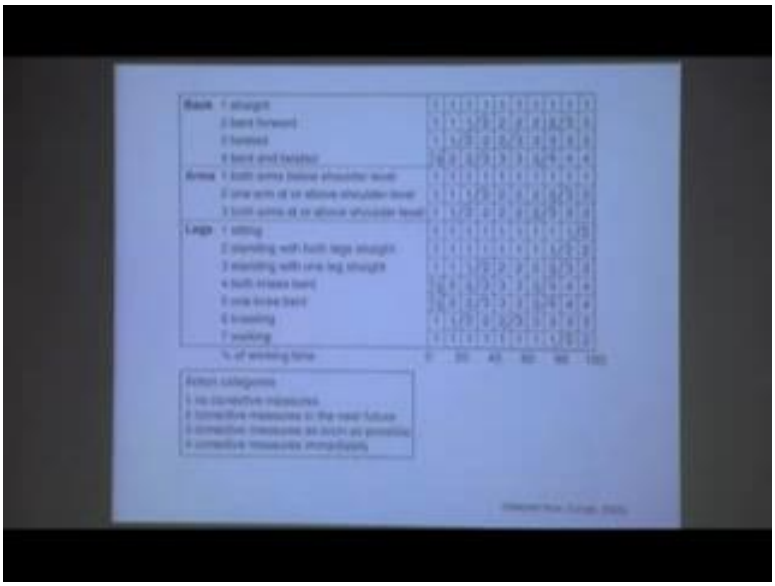

Now, this was just momentary observation. So, after that generally for this OWAS analysis RULA analysis, what we do we have to record the posture? So, in that working condition, we can go for photography or videography, that photography or videography can be recorded for the whole day 48 hours one, all as per your requirement by particular time duration. Out of that working duration, now we can calculate that out of that total working time, how much they have used this particular back for back there are four types of posture. Out of the hundred percent working times, what is the ration of using back in state condition what is the use of back for bend posture. So, that is actually indicated from this table.

Out of 100 percent working time, if back posture if we find the back posture bent and forward; for the total 20 percent time that particular individual during the 100 percent working time, 20 percent time he is actually spending while their back is bent forward. Accordingly we can identify that back bent forward this is the back posture and for which duration they have calculated that. So, bent forward with the particular posture, the person is a 20 percent of the working time; he is spending with bend posture. So, now his score is coming at 1. But if out of hundred percent working time if for back posture, if it is bend forward or eighty percent of time then it is coming to score 2. Similarly, for legs if say 60 percent of time that person he is on one knee bent then that is code five for momentary observation leg score is 5, but one knee bent and that person out of hundred percent working time he is actually spending 60 percent time. So, his score is coming to

five bent. So, it is coming at around 3. So, in this way this table is used to indicate which percentage of time that individual is spending with the particular posture of a particular body segment that we may back arm or leg and based on that we can categorize action categories.

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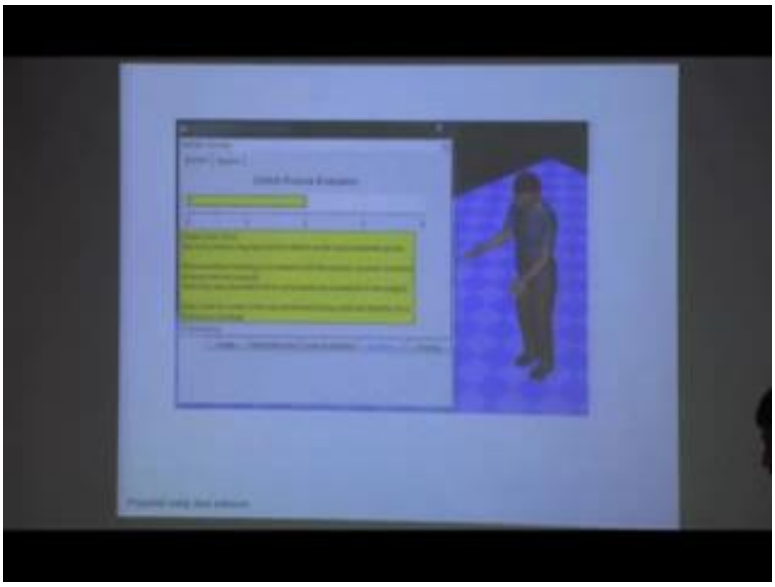

So, four action categories are there, now this is the theoretical background. Now, how we can evaluate with software.

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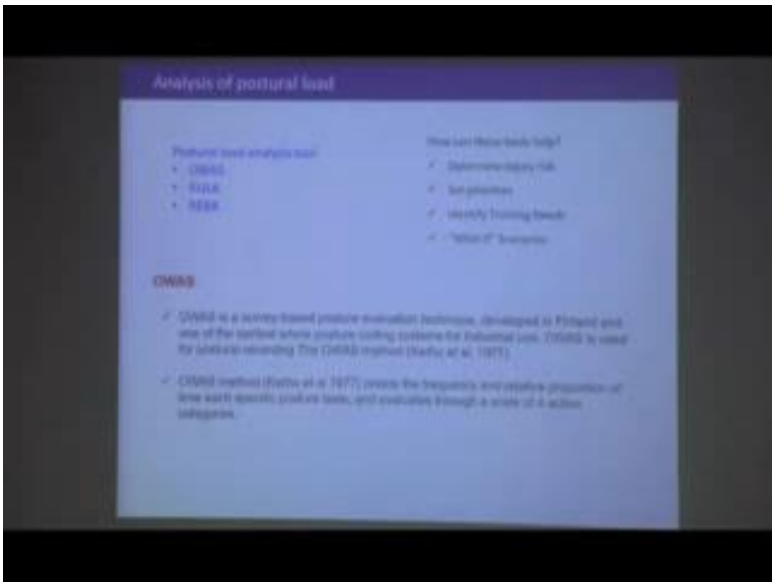

So, just for recapitulation, so in OWAS method what we did for OWAS method this is as we mention this is a survey based method. From this survey based method where people are working then for a particular posture or particular task does not sorry particular (Refer Time: 113:55) for my particular task they have to the observer or who is going for evaluation they have to record that video from that video they have to identify different frames. One is momentary observation for a particular posture for that particular moment, while you can get this type of image or this type of photograph. Based on this particular posture, this is the score. Form this way from the referring this table, we can calculate the grand score.

Another is from videography if we record the total working hours that is the hundred percent working time out of that hundred percent working time which percentage of time is being spend with the particular body posture if we can identify that from that also we can go for suggesting various action categories. Now, the same thing we can evaluate with digital human modeling software while we are using digital human modeling software then our task is much more easier. Because while we are doing it manually we have to record photography photograph then for videograph then after that we will have to identify various postures we have to categorize them. Based on that category, we have to put scores then we have to also study the load or posture used. Then based on that we can calculate grand score and we can recommend specific action category, but in digital human modeling software it is very easy where we can select the particular human with the particular working posture. This is obviously, momentary observation there is no effect of time if we want to go for affect of time then we have to define all those variables.

So, here this is OWAS posture evaluation tool, while we are evaluating this is from jack software. In jack software, if we select that human with a particular working posture and go for working posture analysis then you will find this type of score it is directly giving you the score and below that score, it is given which action category is applicable. So, in this particular case OWAS coding is coming to triple one that work posture may have harmful effect because it is coming to two. So, harmful effect and muscular skeletal system muscular skeletal loading is not extreme with this posture.

However, corrective measures are encouraged note that only downward force components are considered in the analysis, because that force has been from this load

downward force has been defined. So, this is showing here OWAS code for lower limbs was determined using loads and weight force distribution strategy. So, in this particular posture we can define the load in different body parts or force exerted by particular body segments. After that based on that posture and based on the load distribution, this software can calculate the posture analysis score as per the OWAS method and based on that postural score it is giving the recommendation in which action category should be followed.

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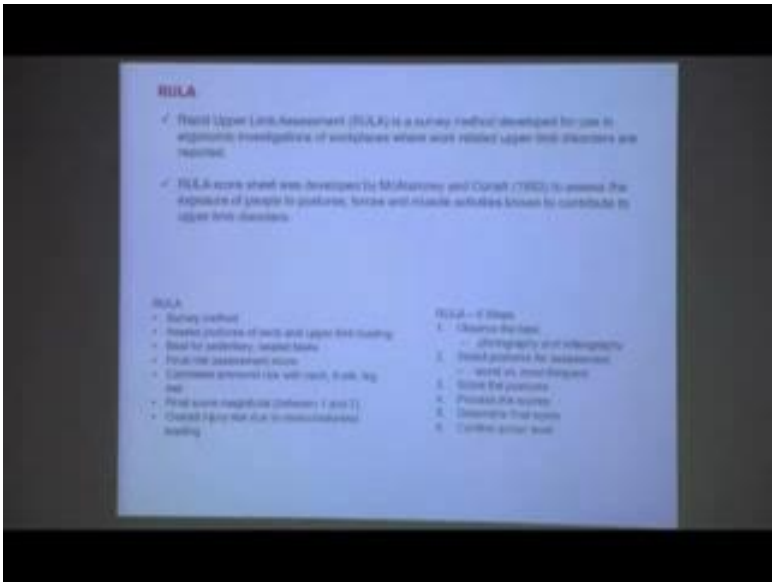

Similarly, in other software also posture analysis tools are available OWAS tools are available and we can evaluate working posture analysis we can perform then next another posture evaluation method that is called RULA. So, first one was OWAS overflow working posture analysis the next one is RULA rapid upper limb assessment this is also a survey based method. So, rapid upper limb assessment is a survey method developed for using ergonomic investigations of work places where a work related upper limb disorders are reported. So, in that scenario, RULA is used; RULA score sheet was developed by Mcatamney and Corlett 1993 to assess the exposure of people who postures forces in two different types of postures force and muscle used known which are known to contribute to upper limb disorder.

So, this factor posture force and muscle use the muscle activity based on that actually RULA calculate the grand score. So, in summary, RULA is a survey based method asses

postural score based on name posture of name upper limb loading based. This method is good for sedentary and seeded tasks because only upper limb is involved mainly in this evaluation because in this case there is no separate score for lower limb analysis. So, this is good for this RULA analysis is good for sedentary work and seeded work.

Finally, it provide final risk assessment score combines arm wrist risk with neck trunk and leg. So, these are the body segments based on the posture of the body segment. It provides the score final score magnitude it varies from 1 to 7 overall injury risk is due to muscular skeleton loading for RULA method there are total six step first is like OWAS also here is observe that task. So, we have to get for photography and videography first we need to observe the task that how people are performing the particular task and what posture are they are looking.

Next, second step is select postures for assessment to identify out of those. So, many types of postures which are there adopting during the posture which are the key postures or which are most frequently adopted by them. So, out of various types of postures for a particular task, we need to identify most frequently the postures which are most frequently been adopted and which are the upward or OWAS posture which needed evaluation. Next, calculate the score of this posture process the score and determine a final score, what is the final score and accordingly suggest various action categories.

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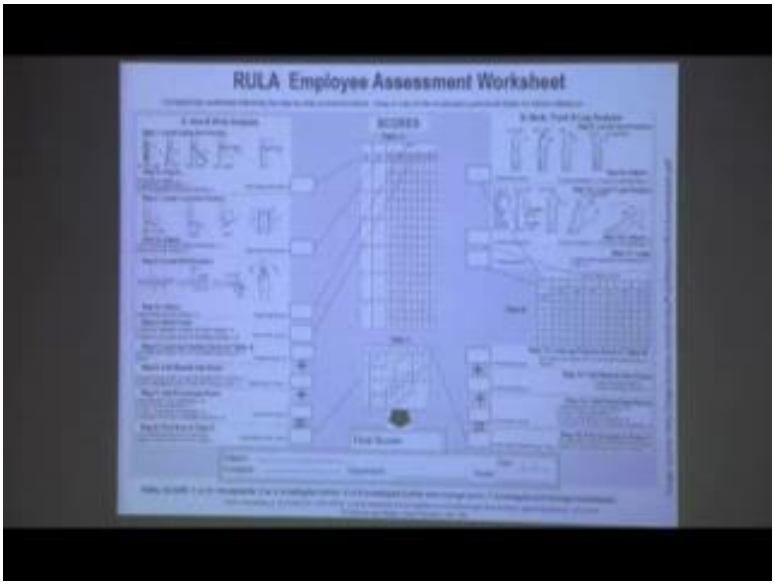

Next this is called RULA assessment sheet; in this different parts and how that body parts should be given defined score is explained. So, first is part a where arm wrist analysis performed then there is second part where step two. So, first part arm wrist analysis second part neck tongue and leg analysis. So, from part a, we are getting score from table a; from part b, we are getting there is another table - table b, we are getting some score. Then with that we are next with that we are adding look up posture score in table b then step add muscle used score then ultimately based on this we are from then we refer table c where from we can calculate the final score.

So, now if we go step-by-step, so first portion is arm and wrist analysis, so based on the posture of arm these is the scores for upper arm. So, based on various posture of upper arm we can get the score. So, all the scores are mentioned that if upper arm posture is like that then you have to calculate one then if upper arm posture is like this then we have to add force. So, in this way, scores are defined. Similarly, score is also defined for lower arm similarly for wrist posture it is defined. So, from that here, we will find some score for upper arm these are the score one two three four in this way total six scores are there for upper arm.

Similarly, for a lower arm these are the scores for lower arm after that we are putting the scores for reached then step four. So, this is the first three steps. Step four wrists to each. So, if they are in these two each then for that purpose also we have to some add some score then step five look up posture score in table eight. So, next, you after giving for all these body segments upper arm, lower arm and wrist and these two each based on this criteria, we are putting some score on the in this table a and from that table we are calculating grand score for table a. So, from table a, then add muscle use score for upper arm this is the upper bodies arm lower arm. For that purpose, we have to go for at muscle use score with this whatever score we are getting from here with that we are adding muscle use score then add force use score in this way ultimately we are getting final score find the row in table c.

So, whatever score we are getting from table a, and from that here is this is the score. So, total three table are there table a, which is associated with arm wrist posture, the wrist twist and then muscle use and force use. From this scores, we are ultimately referring this table a. From the table a, we are getting a specific grand score with that grand score while we are adding muscle score and force score, we are getting a score. Whatever

score we are getting that score is actually listed here 1 to 8 plus if say for example, from calculating from table a after that adding muscle score and force score say we are getting six here, so that six we have to this six value next it will be reflect to table c. So, these six values are identified. So, this is for this side.

Similarly, the neck trunk and leg, so first portion, we are evaluating the neck posture. Based on that score, what is that score trunk posture based on that, what will be the score while these two are identified trunk posture score and neck score. Based on that from table b we are identifying some score while the score is identified with that score we are adding muscle use score and force or load handling score after adding this two you are getting a score that score again will be referred to table c. So, table c has two this is horizontal axis this is vertical axis in horizontal axis it is actually referring the score from this, this side, we score from b table b with that muscle score with a force use score.

So, whatever grand score, we got for the upper body portion this neck trunk. And with that after adding muscle use score and load or force handling the whatever grand score we are getting we are referring here this particular row of table c, where 1 to 8 plus score is mentioned for table c. Similarly, for arm upper arm lower arm reached we are referring table a, whatever score we are getting, with that score we are adding muscle use score force use score whatever. Final score we are getting that score again we are referring to this vertical this column where we are identifying say for example, it is score is six and here score is five. So, this seeks for group a and this group b for group b this is score is five. So, based on this six and five from the table we are identifying the final grand score and the final grand score there is different action category based on that action category we have to decide. So, there are as we mentioned here there are total one to seven action categories.

If we find what is our final grand score, if we find our final grand score is high then as per that we have to go for recommendation. So, recommended final score here it is mention one or two then it is acceptable as in the particular example as we are assuming that our final score is five from table c then actually it is coming within this range five or six. So, investigate further and change the posture soon. So, we have to investigate further and we have to (Refer Time: 127:43) the task (Refer Time: 127:44) the works in such a way, so that this postural score can be reduced.

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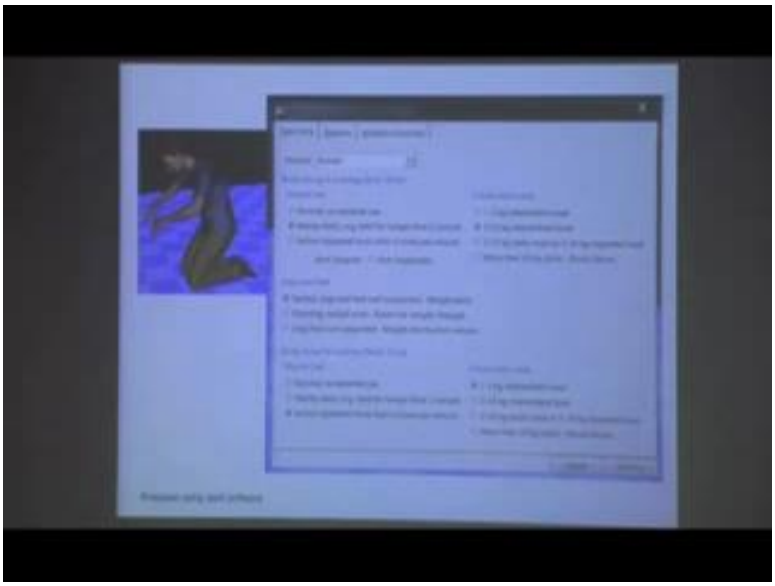

Now, this RULA can be generating with digital human modeling software where the manikin or digital human model while performing a particular task with a specific posture. In the posture, if you select the human and you define various muscle used already posture already identified by the software based on the body joints, so that is already identified. With that, we have to add muscle use force and load handling and legs and feet whether those are supported or not, whether these types of options are there. This is for group a as we have already discussed group a. Similarly, for group b whether there is muscle use and load or force handling that you have to define. So, body group a arm and wrist for that these are the three components muscle use force and leg for group b there is muscle use and force angle loads because overall posture is already been identified.

If you go back this one, so for group these are the things where arm wrist and legs are involved, with that muscle and forces are involved. Similarly in group b, neck trunk legs are there with the muscle and force has been added and finally, we get the grand score. An software already posture is identified additionally we have to add this thing for group a, that is muscle use force use and leg and feet condition. And for group b, again you have to define the muscle use and force. Based on this data, it will ultimately give this type of grand score.

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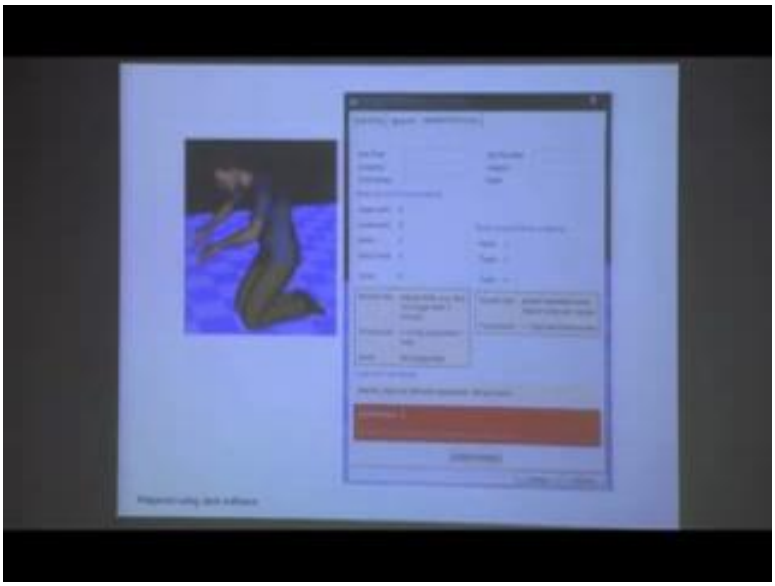

So, here based on the input parameter it is giving grand score of 6, and accordingly action categories investigate and changes are required soon. So, based on grand score 6, it is giving the recommendation. So, in digital human modeling software here we are giving from jack software. So, for two segments of body parts we are defining the body joints muscle use, load use and posture is already been identified by the software. Based on that it is giving the score; and the based on that score it is giving the recommendation. So, it is very much easy to use.

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Similarly, in CATIA software, there also you can evaluate RULA. There if you want to go for RULA evaluation then we will find this rule this is called gear posture this tool name is RULA. For that purpose, what we need to do we have to give particular posture to that manikin for which we want to evaluate that RULA score.

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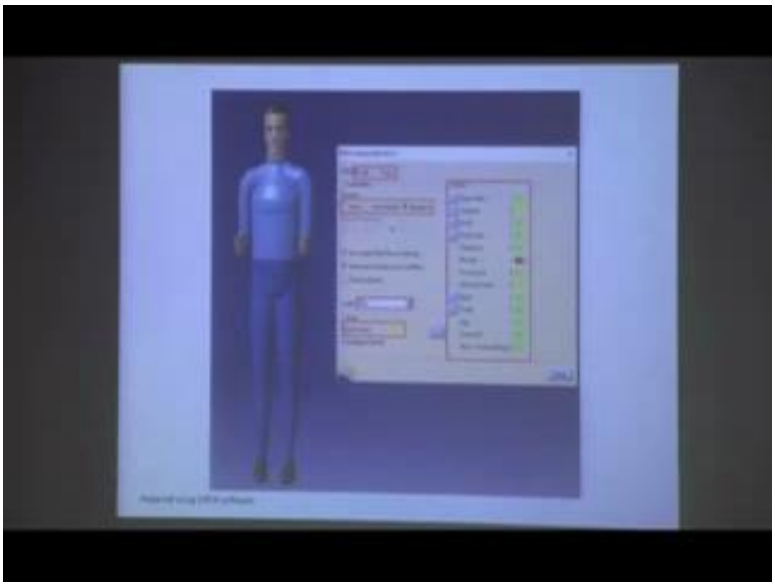

Then this RULA analysis window will open, where you have to specify because in RULA analysis we have to evaluate our left side of the body or right side of the body separately both cannot be calculated together. So, first you can calculate because left hand or left leg that posture of the left hand or left leg may be defined for right side of the body. I mean posture of left hand may be defined from posture of right hand; similarly, posture of left leg may be defined for right leg, so that is why left side of the body is evaluated separately from right side of the body.

So, in RULA analysis, so if you go for left side analysis first. So, few body parts which are common which is head trunk for that there is no left right, but for other hand and leg we need to go for left and right side of evaluation. So, side, it is indicated here left, we are evaluating left side then type of posture whether static, intermediate or repetitive that we can mention. Then (Refer Time: 132:04) frequency how frequently the particular body parts are moving we can also mention the task is being performed that also we can give. Then the conditions of arm are supported or not, whether it is body is balanced or not based on all this criteria and also whether they are handling any load that we can

give. While all this things are defined based on that it is giving the final score; not only final score it is also for individual body segments what is that score that is also being provided.

Based on individual body parts score, it is giving the final grand score and the grand score is 3 and it is indicated with yellow colour. It means investigation further required. So, in this way, with this digital human modeling software, we just discussed with the example of from jack software and CATIA software, but most of the digital human modeling software has the capability of evaluating this type of postural load using various postural evaluation tools like RULA, REBA, and OWAS.

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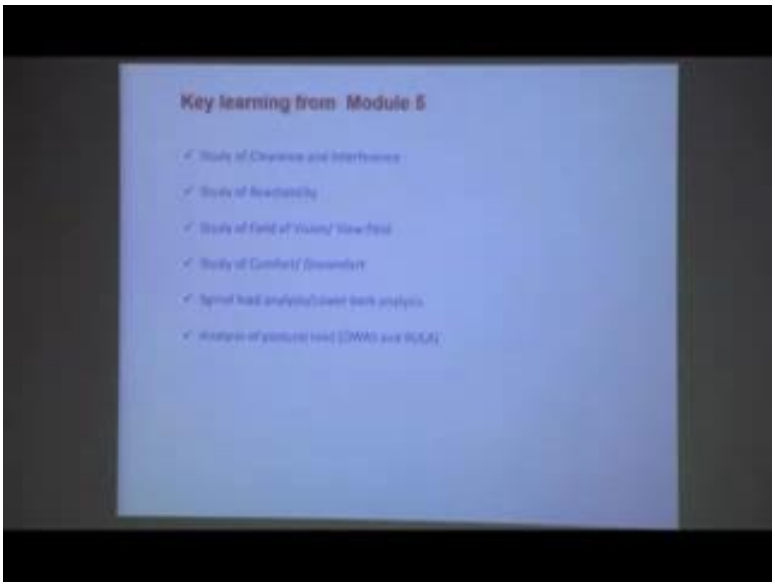

Now, we are moving to key learning from this module 5. In module 5, we discussed about from the very beginning we recapitulate we find.

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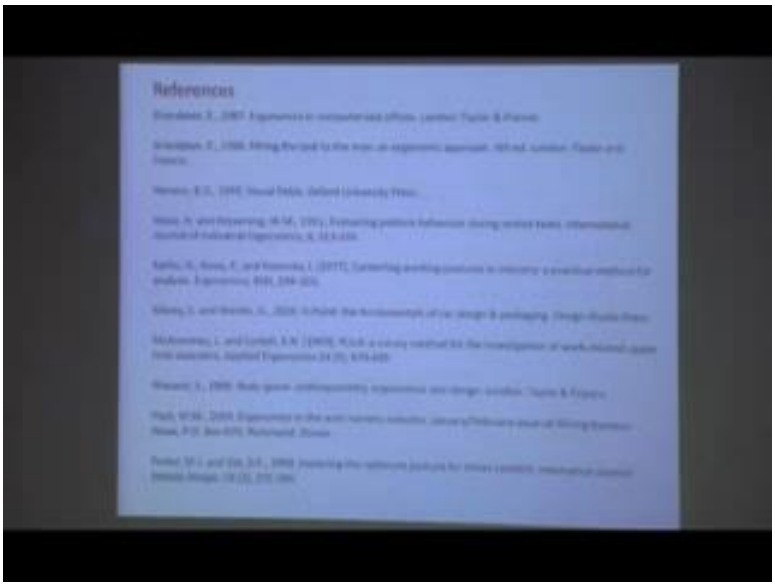

We have discussed about study of clearance, dimension and inter clearance and interference. So, where we discussed about head clearance, leg clearance, thigh clearance, lateral clearance and we will explained how we studied the theoretical background at the same time we demonstrated with jack or CATIA software that how software tool can be used for evaluation this clearance and interference where we have also discussed about collision detection techniques.

Then we move to reach analysis. So, after starting various theoretical aspects then we mention how reach is evaluated with digital human modeling software where we discussed about extended reach normal reach at the same time comfort reach and reach constraint driven reach. So, various types of reach can be evaluated with different types of tools available in this software, so that reach analysis also being performed and shown.

Next, we discussed about field of vision or view field in field of vision or view field we discussed about eye view, view angle, view cone then eye view window, reflection zone, obscuration zone. So, different types of tools which are available in digital human modeling software and with those tools how we can evaluate vision or view field that has been discussed.

Next, we discussed comfort and discomfort. So, comfort and discomfort analysis in digital human modeling software is performed with you performed mainly based on the

body joint angles. And based on the comfort range of that particular body joint, we can define that whether the particular body joint is within comfort range or not. And if it is in many of the software, there is colour coding option and colour, if the particular body segment is highlighted with a specific colour to indicate whether that is within comfort range or not.

Then we discussed about spinal load analysis, and low back analysis. Here we mainly discussed about spinal compression force at L 4-L 5 segment and also shearing force at L 4-L 5 vertebral segment. So, how much inter vertebral this pressure is there that we discussed here. Then we evaluate then we discussed about postural load analysis using various ergonomic evaluation tools for posture like RULA, OWAS and also we demonstrated with software use. So, this is the overall learning from module 5.

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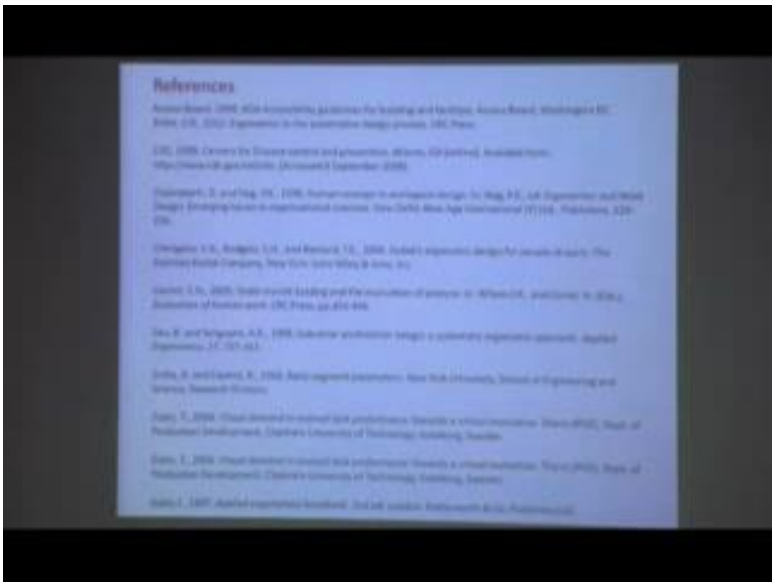

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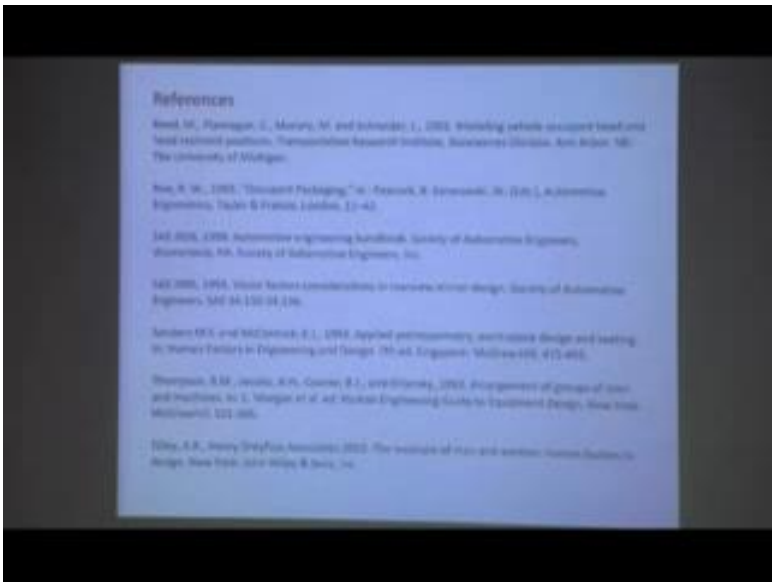

Now, these are the references these references have been cited in different slides. So, students can go through these references, they can explore to get more information regarding this tools or different information which has been provided in various slides.

Thank you.