# Digital Human Modeling and Simulation for Virtual Ergonomics Evaluation

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## Lecture – 15
## Techniques/Process of Virtual ergonomics evaluation using DHMs Part B (Part II)

In continuation to our earlier discussion regarding application of digital human modeling software in different types of industries or operational sectors; so, already we have discussed about application in automotive industries.

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Now, we are going to discuss application of digital human modeling and simulation in the field of health care industry. Presently, this digital human modeling software is being used in various aspects of healthcare simulation and this is used for healthcare education, medical training, medical research and practices. And, in many of these cases, not only digital human modeling software, but also various virtual reality systems are being used. In this, both the digital human modeling and virtual reality are used together in many cases for all these purposes.

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Now, in subsequent slides, we are going to discuss about how digital human modeling software is being used by various researchers in healthcare industry for either for medical training or medical education or for different types of medical practices or medical work place design. So, now we are discussing a particular paper written by Marcos et al. 2006. So, in the paper entitled computer simulation for ergonomics improvements of laparoscopic surgery; in this paper, Marcos et al. demonstrated how digital human modeling can effectively be used towards ergonomic design of laparoscopic operation room to ensure increasing overall safety and efficiency by reducing the postural stress of the medical staffs.

So, here we will discuss them by various images taken from those papers and how they have used this digital human modeling technology. Since continuous observation of screen and positioning this screen, position on the bulky trolley with equipment is mandatory for each member of the team; they have to undergo awkward posture and static working posture for prolong duration, In laparoscopic surgery room, surgeon as well as nurses or clinical staffs they have to undergone the awkward working posture and that is also static in nature for prolong duration, because there is requirement or they have to continuously look at the screen for performing their activity.

So, in the research reported by Marcos et al, they used CATIA software for modeling operating room and RAMSIS software for developing digital human model. Apart from these two software, PCMAN software are also used for extracting 3D wireframe model of the working posture from two synchronized video spots of different viewpoints. These models were used for providing posture to the manikin in RAMSIS software.

So, while those medical staffs or surgeon working in that workplace, then videography was taken and from that videography, two videoframe from two different viewing angles were taken and those video on the videoframe, this type of wireframe model was put by PCMAN software. And, in that PCMAN software that 3D wireframe model ultimately developed. That 3D wireframe model developed from specimen software was actually used for developing digital human model in RAMSIS software. So, PCMAN software; what actually in this case PCMAN software did; PCMAN software developed the wireframe model from the 2D images and that wireframe model ultimately used for developing 3D digital human model in RAMSIS software. Then, an ideal working posture of the surgeon was defined based on the demonstration of comfortable posture by two experienced surgeon.

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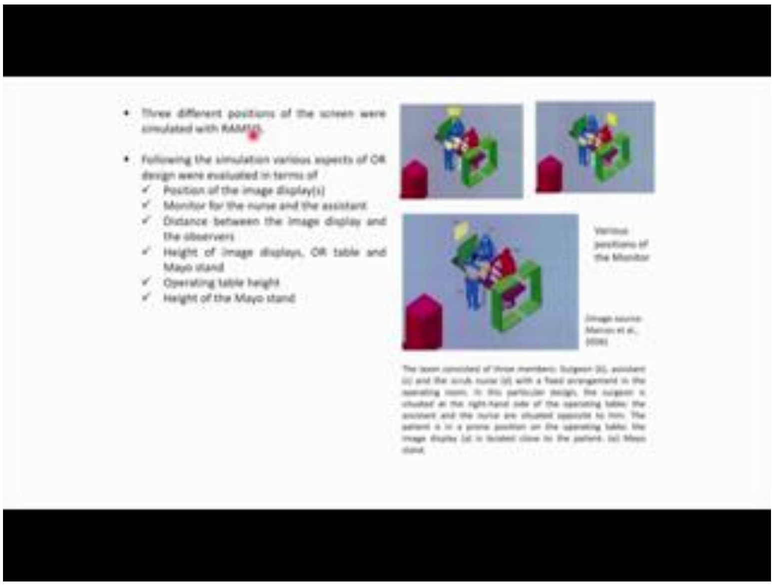


Three different position of the screen were simulated with RAMSIS software. So, there are three images. In the first images, this is the actually screen or display where both in this workstation means in laparoscopic surgery room, mainly three people are involved one is surgeon and two are the medical staff or nurses. So, here this yellow color one is the display or screen; then, this green color one is the Mayo board. And so, in their study, they simulated three scenarios. In one case, the display is kept diagonally, where the surgeon can see, but this is not comfortable to visualize by medical staffs or nurses. In another case, it was kept just opposite the surgeon, backside of the medical staff.

And, in the third case, it was positioned towards the head side of the patient – means in this position, surgeon as well as medical staff can see this display, but they have to turn their neck. So, these three simulation conditions were considered. And then, various types of ergonomic evaluation are performed by the researchers. Following the simulation, various aspects of operation room design were evaluated in terms of position of the image displays, monitor for the nurse and the assistant; distance between image display and observer; height of the image display, operation room table and Mayo stand. Next operating table height; height of the Mayo stand; so all these factors actually considered during this simulation study.

So, here various components – a, b, c, d; in this image, a, b, c, d, e has been mentioned for various components of this workstation or workplace. So, the team as I mentioned, the team consisted of three members: one is surgeon, that is, b – this one then assistant c and this is assistant c; and next, the scrub nurse, that is, d. So, these three persons are involved there. In this particular design, the surgeon is situated at the right side of the operating table; and, the assistant and the nurse are situated opposite to him. So, one side surgeon is there and opposite side scrub that nurse and that assistant is there. The patient is in turned position on the operating table. This is the image display and, this green color one is the Mayo stand. So, this is the overall setup in that operation room.

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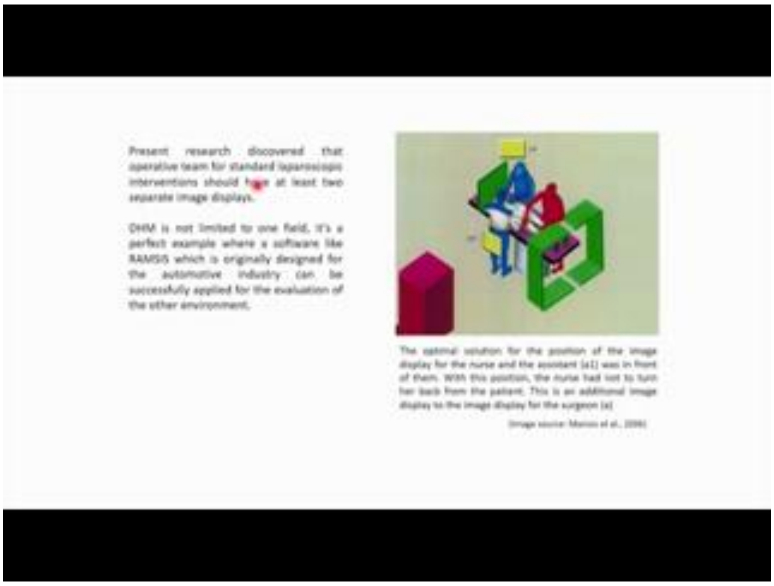


So, present research discovered that operative team for standard laparoscopic observation in a laparoscopic intervention should have at least two separate image display. So, following this ergonomic evaluation in that simulated environment; so, researchers found that, at least two image displays are required: this is a and a 1. Otherwise, it is very difficult to give comfortable view for both, that is, the surgeon and also for nurses and assistant. So, two image displays are very essential; digital human model. So following their study they concluded that digital human modeling study limited not only limited to one field; it is a perfect example is this present case. Although in this particular case study, RAMSIS software has been used, which is mainly popular for automotive industry, because RAMSIS is good for automotive ergonomic evaluation, but the same RAMSIS software has been used in this case for laparoscopic surgery operation room design. So, this is one example, which indicates that, RAMSIS software or any software developed by particular industry is not only restricted to that particular industry; it can be used for other industry also.

So, in this image, it is showing the optimal solution for the position of the image display for nurse and assistant, that is, a 1. This display is for nurse and assistant. And, this display a is for surgeon. This is an additional image display to the image display for surgeon a. So, total two displays have been used in this case. So, what we can find? So, in their study, Marcos et al. through that simulation study, they clearly demonstrated that, what should be the optimal position of the display; at the same time, how should be the height of the Mayo stand, operation table and various other factors as described here, so that people who are involved that is the medical staff, nurse and the surgeon they can do their work comfortably.

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In another study by Hanson et al., they demonstrated how digital human modeling tool can be modified and used to evaluate bathing system design for caretakers and caregivers from ergonomics view point. So, their research paper entitled application of human modeling in health care industry. In this paper, they described how digital human modeling software can be used for this designing bathing system from the view point of ergonomics. Anthropometry, joint range of motion, description and appearance of the manikin were customized to represent caretakers and caregivers in digital human modeling tool that is Delmia V5 Human. So, in their research, they used Delmia V5 Human model and various aspects, that is, anthropometry, joint range of motion; all these things are customized to represent caretakers and caregivers.

Digital human modeling personas were created for both the groups, that is, the caretakers and caregivers. The standard appearance of the manikin as it is appeared in digital modeling software that was kept for caregivers. But, a more aged corresponding appearance was given for the caretaker manikin. So, this is the caretaker means who is taking the care and this is the caregiver, that is, the nurse. So, in this case, there whatever appearance of the digital human modeling software is available in Delmia software; that has the same thing has been used for caregivers. But, for the caretakers, more aged appearance was provided. Preferred bathing posture was identified from the real life observation and used for this simulation. Task performed by caretakers and caregivers were also defined. After the study, the project was aimed at designing a new footrest to be integrated in the new bathtub design. So, following their analysis, they ultimately proposed a new the bathtub design, where they also proposed for integration of a footrest; that is shown here.

So, this is first, in Hanson et al. studied the bathing posture; based on the bathing posture, they provided the bathing posture to the digital human model and this is the bathtub. And then, they are going for different types of ergonomic evaluation like ruler analysis. And, based on the ruler analysis, it was possible to identify that which body parts are beyond the comfort range of movement while caregivers are adapting various types of postures for their activities.

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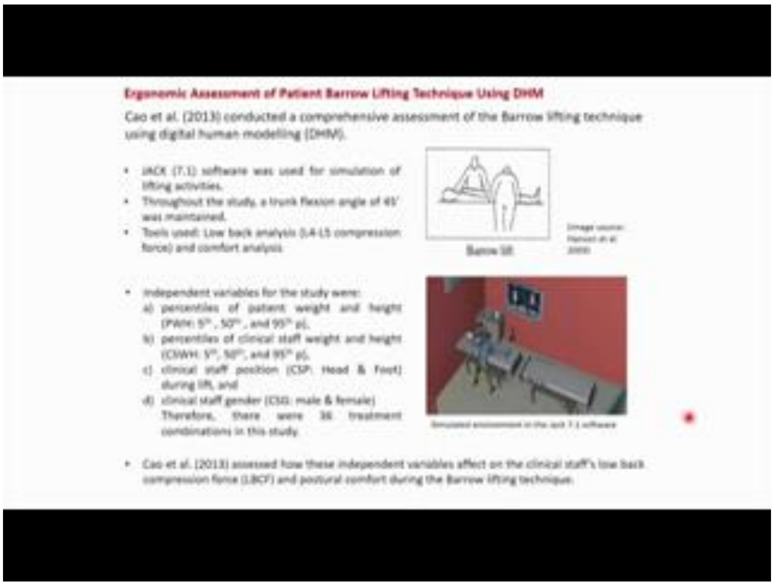


After these two papers, now, in another paper entitled ergonomic assessment of patient barrow lifting techniques using digital human modeling; so, in this paper, Cao et al. 2013 conducted a comprehensive assessment of barrow lifting technique using digital human model. So, first we should know; what is this barrow lifting technique. In barrow this is actually patient handling technique; there are different types of patient handling techniques; one of those patients handling technique is barrow lifting. In barrow lifting, two helpers or nurses are required; one of them actually holds below the neck and one hand at the waist region of the patient. So, first these two nurses or the staffs they first put their hands together: one hand of this person and another hand of this person. They put this hand together below the waist region of the patient; and, another hand is kept below the neck position and another arm of the second person is kept below the thighs. So, in this way, in barrow lifting technique, they hold the patient.

In this research, they demonstrated that, how this barrow lifting technique is affecting the posture and at the same time their spinal load while they are handling the patient. So, JACK software was used for simulation of lifting activities. Throughout the study, the trunk friction angle of 45 degree was maintained. And, what analysis has been done here? Mainly low back analysis, this is the one ergonomic evaluation tool in JACK software that is used for compression force analysis at the lumbar 4 and lumbar in between lumbar 4 and lumbar 5 segments. So, these two analyses have been done: one is low back analysis and another is the comfort analysis. So, these two analyses were carried out for evaluating their activities.

Independent variables for the study were percentile of the patient weight and height; so, three percentiles of the patients are considered: 5th, 50th and 95th. And accordingly, their weight and height were considered; next percentile of the clinical staff there; so 5th percentile, 50th percentile and 95th. Here also three percentiles: clinical staffs according to their weight and height are considered. Clinical staffs' positions were categorized into one towards the head side another towards the foot side. In one, towards this person, towards the head side of the patient; and, another person towards the foot side of the patient. Then, clinical staff gender, that is, male and female. So, ultimately, total 36 treatment combination came. So, these three percentiles into these three percentile conditions multiplied by two staff position multiplied by two genders. So, in this way, 3 multiplied by 3 multiplied – 2 and multiplied – 2; so, total 36 treatment combinations were studied in this particular research.

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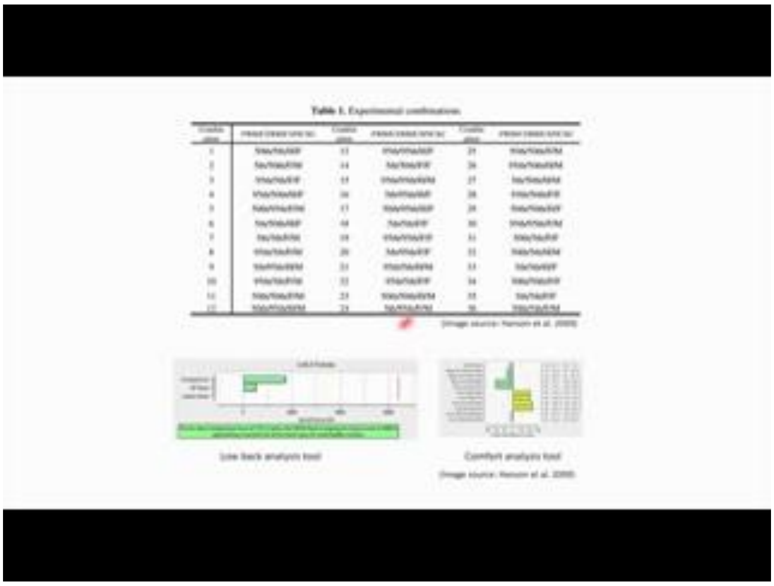

These 35 treatment conditions patient handling conditions are shown in this particular table; say 1, 2, 3; in this way, total 36 combinations are there. And, for each of the combination, ergonomic evaluation for low wall back analysis and comfort analysis were performed. This is the screenshot from that JACK software are l 4, l 5 intervertebral disc compression force was calculated. And, this image shows for different body joint angles, whether those are in comfort range or not. If that particular joint angle is within the comfort range, then it is denoted with green color. And, if it is beyond the comfort range, then it is denoted with yellow color.

Cao et al. 2013 assessed how these independent variables means these independent variables affect on the clinical staffs low back compression force and postural comfort during barrow lifting technique. So, already we discussed this one.

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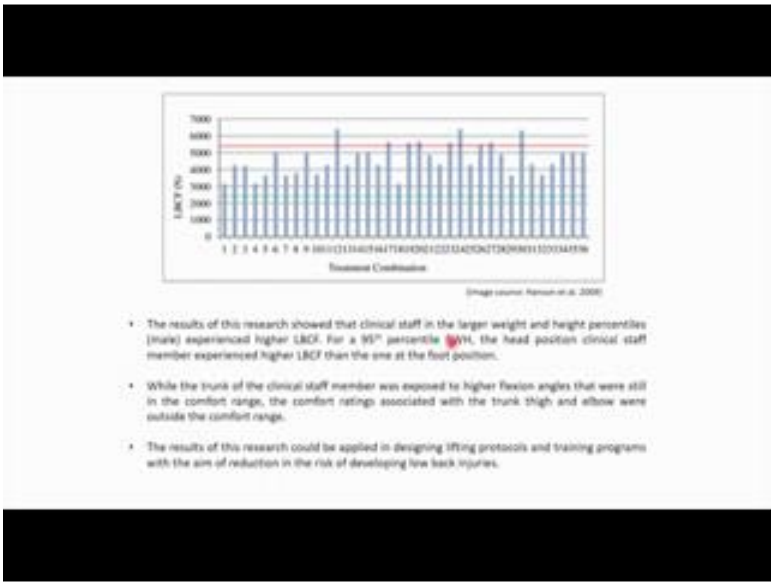


So, this is the actually observation from that low back spinal compression force. And, this is the treatment condition. So, as we discussed treatment condition or patient handling condition. There are total 36 combinations are there. And, for each of the combinations, how is the low back compression force that was measured. So, recommended limit for low back compression as per niosilic T equation; that is approximately 5000 Newton. In many cases, it was observed that, it is beyond the recommended limit or beyond the acceptable limit in these three cases. On the other hand, there are also some cases, where it was below the recommended level also. The result of this research showed that, clinical staff in larger weight and height percentile that is mainly male experienced higher low back compression force. So, male person with higher percentile values of height and weight; they suffered more from low back compression force.

For a 95th percentile patient weight-height, the head position clinical staff member experienced higher low back compression force than one in the foot position. So, while they are handling 95th percentile patient height-weights; then it was found that, among these two clinical staffs, the person who is positioned towards the head side, his low back spinal compression is more than the one is in the foot position. While the trunk of clinical staff member was exposed to higher friction angle that was still in the comfort range, the comfort ratings associated with the trunk, thigh and elbow were outside the comfort range. The result of this research could be applied in designing lifting protocol, training programs with the aim of reduction in the risk of developing low back injuries.

So, in this research through this digital human modeling simulation, authors were able to demonstrate that, how the patient handling can be evaluated in terms of low back spinal compression and comfort; and accordingly, decision can be taken that, what types of modification is required to avoid these low back injuries.

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Next, we are going to another research paper reported by Kouchi and Mochimaru 2011. Their paper entitled simulation of body shapes after weight change for healthcare services. In this paper, Kouchi and Mochimaru developed a system to simulate the body shape after weight gain or loss with the intention to motivate people to follow healthy lifestyle and adopting health actions. Research reported by them mainly targeted middle-aged males, because in Japan, because this study was performed in Japan. And, in Japan, this middle-aged people are mainly exposed to overweight condition. And, the persons, who are considered for this study, their age is starting from 30 years to 59 years. They are categorized in three groups: age below 40, age within 40 to 50, and age more than 50 years.

The body-shape after weight change was simulated by following method. So, a body shape method was body shape model was created for each subject by fitting high resolution template meshes to his scanned anthropometric data obtained from 3D body scanner. A digital human model called Dhaiba, that is, digital human aided basic assessment system, was used as the template. So, for this body-shape representation; first what they did, they scanned with the 3D body scanner, they scanned the body for the particular person. Then, on that particular person's body, they – on the sketch scanned image, they positioned or fitted the high resolution template mesh from with the help of this digital human modeling software called Dhaiba. From scanned image, ultimately they got this type of high resolution mesh image. The models were used for principal component analysis by multiple regression equation to estimate principle component score from nine selected variables. Those nine selected variables are weight, height and seven circumferences of the body. So, after body shape model they created this body shape model and also performed the principal component analysis to calculate the principle component score from nine selected variables.

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Then, seven circumferential dimensions were calculated after weight change. So, while there is weight change either addition or reduction; while weight change happened, then again seven circumferential dimensions were calculated using linear regression equation. After that, principal component scores after weight change were calculated from nine selected variables as we mentioned earlier; that is, a height, seven circumferences of the body and changed weight. Based on these nine variables, principal component scores were calculated after weight change. And, body shape was reconstructed based on this principal component scores. So, as I mentioned earlier; so first scanned image, the 3D body scanner, first they collected the scanned image of the body. Then, on that scanned image of the body, they fitted the high resolution template mesh with the help of this software. And after that this is the following the principal component analysis, they changed the body shape of the digital human model; this is that. So, c is the adjusting the posture and segment length of the body shape model. So, this is the initial body shape after weight change either weight addition or weight reduction; this is the body shape model based on the principal component scores. This model was further adjusted based on the length of the body segments and also it was adjusted for various body circumferences.

So, adjustment of the reconstructed shape model was performed by modifying seven circumferences as per their estimated values and keeping the length of the internal skeletal of the body shape model unaltered. So, while this body shape means this is a reconstructed body shape after the weight change. In the reconstructed body shape, as the height of the body will not be changed, only there is addition or reduction of the soft tissues. So, skeleton dimension was kept fixed; body circumferences, which were estimated, based on the linear regression equation, these body total seven circumferential dimensions were adjusted to achieve this final model. So, this final model actually represents how a person will look after the weight change. So, this was the initial look; and how was the modification after the weight change, how he or she will look.

In this particular image, it is shown comparison of scanned body shape. This is before and this is after. So, for a person whose height is 169 centimeter, weight – 69.5 kg and basal metabolic index is 23 – 24.3; and, simulated body shape after weight increase. How much weight was increased? 15.5 kg. For this person, 15.5 kg body weight increase; then, this is the body shape. So, their system can demonstrate this type of body shape after the weight change. So, if we define that, this much of weight has been increased for a particular person; then, how he or she will look. Similarly, with this, the system can also be used for weight reduction also.

The simulated body shape after weight change demonstrated by Kouchi and Mochimaru 2011 was based on principal components derived from inter-individual variation. So, their system was actually dependent on the inter-individual variation of body shapes. So, principal components derived from inter-individual variation of the body shapes. Thus, sometimes the reconstructed body shape was found unnaturally different from original body shape, because it is dependent on the inter-individual variation. But, in real life, what is actually required, that is, intra-individual body shape variation – means for a particular person, when for he or for her, there is weight change; then, how will be the body shape after that weight change. For that purpose, we need the principal component analysis for intra-individual variation. So, thus, sometimes the reconstructed body shape was unnaturally different as it was followed or it was based on intra-individual variation. So, Kouchi and Mochimaru mentioned that, longitudinally collected body shape database is required, that is, the intra-individual shape variation to solve these issues, so that that unnatural body shape would not come, if we can use the intra-individual shape variation.

The study is expected to be usable in fitness club for motivating people to start and continue physical exercise or adopting healthy lifestyle to combat with overweight or underweight condition; because ultimately a system, which they develop that system is capable of representing that how someone will look or how someone's body shape will be changed due to O X change; that can be easily demonstrated by the system. If someone's come to this in front of the system and if they find that, after this much addition or this much reduction of the body weight, their body shape will look like this that, then they will be inspired to do regular physical exercise or changing their lifestyle.

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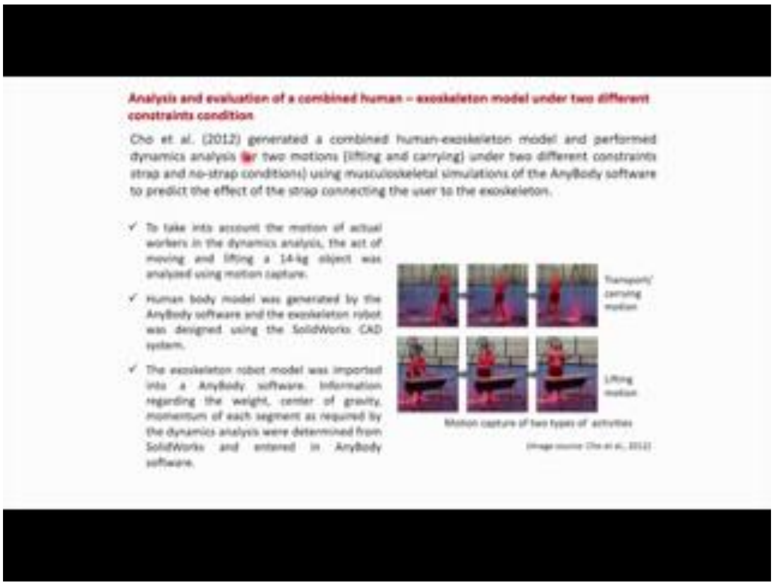


Cho et al. 2012 in the research paper entitled analysis and evaluation of a combined human exoskeleton model under two different constraints condition; in this reported research, they generated a combined human exoskeleton model and performed dynamic analysis for two motions: one is lifting and another is carrying under two different constraints, that is, two different constraints: one is strap condition and another is no strap condition using musculoskeletal simulation of AnyBody software to predict the effect of strap connecting them and how that strap affecting a person while he or she is using that exoskeleton system.

To take into account the motion data of actual workers in the dynamic analysis, the act of moving and lifting a 14 kg object was analyzed using motion capture system. So, in this image, it is shown that, two work activities were captured through motion capture system: one is transport or carrying motion and another is lifting motion lifting the object from the table. In both, this was recorded with 3D motion analysis system. Next, human body model was generated by AnyBody software and exoskeleton robot was designed using SolidWorks CAD system. So, two software they used: one is AnyBody software for digital human modeling and SolidWorks CAD software for designing the exoskeleton. The exoskeleton robot model was imported into AnyBody software. Information regarding weight, center of gravity, momentum of each segment as required for dynamic analysis were determined from SolidWorks software and entered in anybody software.

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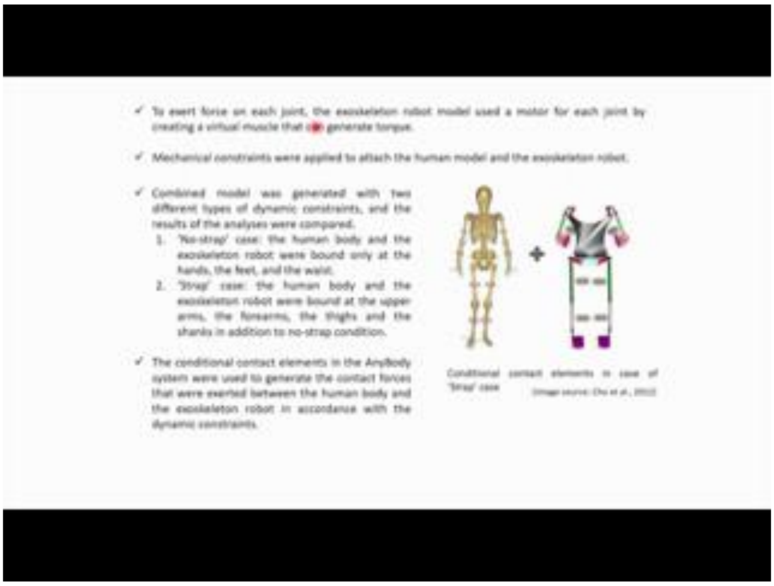

To exert force on each joint, the exoskeleton robot model used a motor for each joint by creating a virtual muscle that can generate torque. Mechanical constraints were also applied to attach the human model with the exoskeleton system. Combined model was generated with two different types of dynamic constraints. And, that result of the analyses was compared. So, for dynamic analysis, two constraints were considered: one is no strap case; another is strap case. And, in both the cases, dynamic analyses were performed and compared to each other. So, first one is a no strap condition. The human body or human model and the exoskeleton robot were bound only at hands, the feet and at the wrist, at the waist in these three points. So, exoskeleton in no strap condition is defined as the condition, where exoskeleton model is attached with the human model at these three points: hands, feet and waist.

And, strap conditions were defined as the human body and the exoskeleton robot were bound at the upper arms, forearms, thighs, shanks in addition to the no strap condition. So, in no strap condition, all the three places, where it was already there was a strap. Apart from that, additionally, the straps were attached at upper arm, forearm, thighs and shanks. So, here from this image, we can see conditional contact elements in case of strap case. The conditional contact elements in the AnyBody software were used to generate the contact forces that were exerted between the human body and the exoskeleton robot in accordance with the dynamic constraints.

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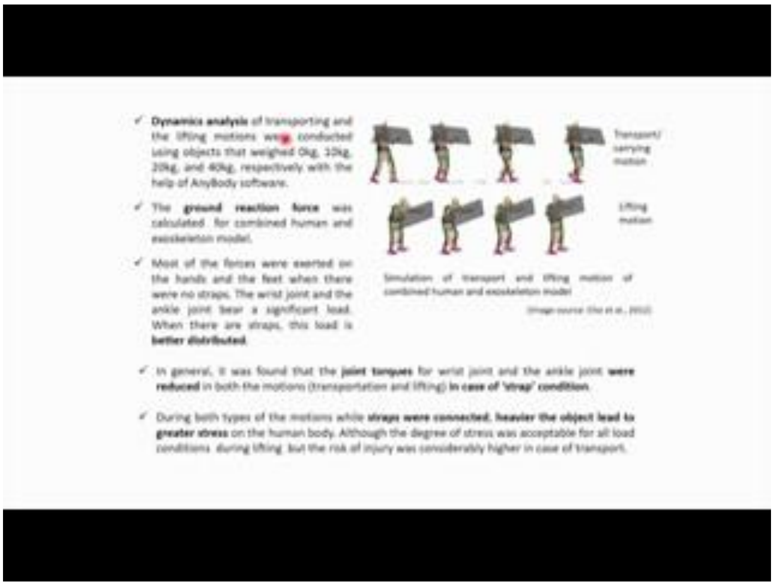

Dynamic analysis of transporting and lifting motions were conducted using objects that weighed 0 kg, 10 kg, 20 kg, and 40 kg respectively with the help of AnyBody software. So, in the next step, dynamic analysis was performed for both the activities that is transportation and lifting for various load condition or weight condition. So, here you can see this is a transport and this is a lifting. While the combined model in both exoskeleton human model attached with the exoskeleton model is carrying an object and here is the lifting of the object. The ground reaction force was calculated for combined human and exoskeleton model.

Most of the forces were exerted on the hands and the feet when there were no straps. In no straps condition, two straps we mentioned in the earlier slide; that one is no strap case, another is strap case. During no strap case, most of the forces were exerted only in the three points, that is, the wrist joint and ankle joint, because there are total three. Their connections are at three points, that is, the wrist and joint as we mentioned in no strap condition. So, it was attached at the hands, feet and the waist. As only at the three points, exoskeleton is connected with the human model. So, most of the forces are exerted on hands and the feet in no strap condition. The wrist joint and the ankle joint bear a significant load in this case.

When there was a strap means strap condition, this load is better distributed in various body parts, because in this strap condition, various body segments are actually attached through the strap with the human model. In general, it was found that, the joint torques for wrist joint and ankle joint were reduced in both the motions in case of strap condition. During both types of motion while straps were connected, heavier the objects lead to greater stress on the human body. Although the degree of stress was acceptable for all load conditions during lifting, but risk of injury was considerably higher in case of transportation.

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From this study, it was concluded that performing a simulation based analysis on the reaction force exerted by exoskeleton robot on user would reduce the product development time and cost, and help ensure the safety of the product. Following their observations, Cho et al. 2012 recommended the use of straps for exoskeleton while there is requirement of handling an object of large mass as straps were found to be lessen the fatigue. So, ultimately from the research, they found that if straps are used to attach the exoskeleton model with the human body; then, there is it can lessen the joint fatigue in comparison to the no strap condition. And, based on that observation, they recommended that, it is better to use the strap condition while the workers are handling larger loads or larger masses.

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Now, we are going to another research paper, where also digital human modeling software has been used for healthcare purpose. In this case, the title of the paper is a virtual human for lower limb prosthesis setup. In this research, Colombo et al. demonstrated that use of virtual humans to validate lower limb prosthesis design and functioning. The first described the state of the art on virtual humans' techniques and main features of the new design framework, which they proposed for prosthesis design; then, the application of virtual human for prosthesis setup. Key elements of their proposed design framework are digital model of the anatomical district that is, the residual limb for socket modeling and the amputee's avatar to validate the prosthesis design. These are the two key components.

The framework guides 3D modeling task for task of the prosthetic design around the patient's stump and the selection of standard and custom fit prosthesis components depending upon the patient's characteristics, that is, anthropometric data prosthesis to be used daily or sport activities and stump morphology. So, in that, there are developed frameworks. So, first, developed a framework to guide the people, who developed the prosthesis, in the system, modeling the framework guides are 3D modeling task of the prosthesis socket design around the patient's stump. So, if you look at this image; so, what is required for prosthesis design, the overall framework is given here. So, database of patient characteristics means his anthropometric data, his prosthesis condition, then dimension of the stump; all these informations are provided. So, that is actually used as knowledge based framework; and, various types of rules are also considered for prosthesis design. So, that is a first step.

And then, those data are used for various purposes. So, people, who are designing the prosthesis they collect 3D CAD models of various prosthetic components. They are from the database of the standard parts – means prosthesis parts. From the standard database that is already developed and stored as the CAD models; from that database, the required CAD models for various components of the prosthetic limbs are collected. This area is coming under prosthesis modeling lab. In prosthesis modeling lab, first step is to identify the parts of the prosthetics from standard parts database.

And, next another is virtual socket lab. In virtual socket lab, first information regarding the stumped body part is required. So, for that, MRI scan data of the stump portion is first taken. From that, wireframe mesh is generated. And, on that stump model; so, first, in virtual socket lab, the stump model is generated. On that trust stump model, the socket is designed in the CAD software. So, first through the MRI scan, stump model is generated. From the stump model, then the socket is designed. After socket, while that socket is designed on the stump body parts and the standard prosthesis components are ready. Then all these components are actually sent to virtual testing lab. In virtual testing lab, virtual testing of the assembled parts with the human stumped body parts or this prosthetic assembly is attached with the digital human model for virtual testing different types of gate analysis or motion analysis.

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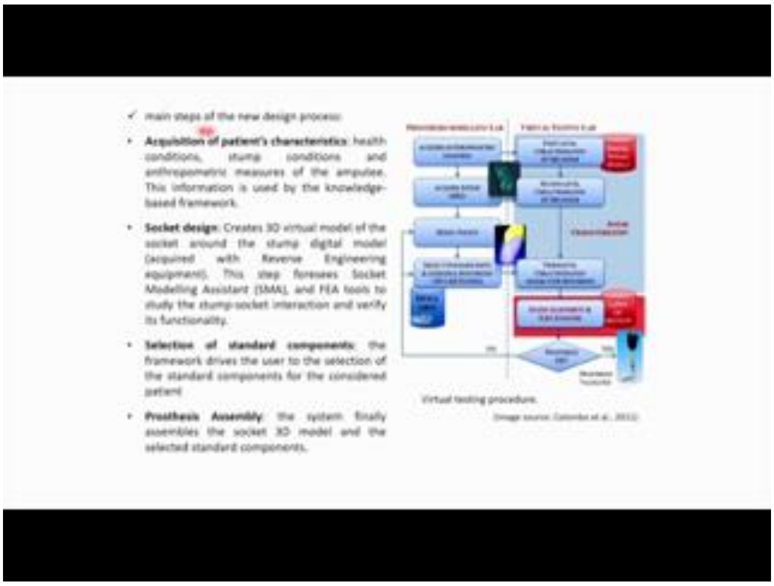

Main steps for the new design process; first acquisition of patient's characteristics, that is, health condition, stump condition and anthropometric measures of the amplitude. This information is used by the knowledge based framework.

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So, this is that middle portion. In the middle portion, all these information's are collected. Then, socket design creates 3D virtual model of the socket around the stump digital model acquired with the reverse engineering equipment. This step foresee socket modeling assistant and finite element analysis tool to study the stump socket interaction and verify its functionality. So, this in virtual socket lab ultimately this socket is designed following this socket design process. Selection of standard components, the framework drives the user to the selection of standard components for the considered patient. So, this is that CAD lab. In that CAD lab, that standard component is selected for that particular patient. Then, prosthesis assembly, the system finally assembled the socket 3D model and the selected standard components. So, 3D socket model; this is the socket model and the standard components are assembled.

Next, to create and simulate the patient's virtual human LifeMOD software were used. Virtual testing, an avatar of the patient wearing the prosthesis is created; by which it is possible to execute prosthesis setup and evaluate its functionality simulating postures and movements. For virtual testing of the prosthesis setup, there are two steps: first patient avatar characterization from the anthropometric and ergonomic point of view; and, second is the gate analysis. If we look at this image; so, there are two parts: one is prosthesis modeling lab and another is virtual testing lab. In prosthesis modeling lab, so, how? Here it is mentioned that there are two steps of prosthesis. For virtual testing of the prosthesis setup, there are two steps: patient's avatar characterization from anthropometric and geometric point of view. So, how the patient's avatar is characterized? For this purpose, if we look at here; so, first acquisition of anthropometric measures; that anthropometric dimensions actually help in first level of characterization of the avatar; means that is the digital human model.

In virtual lab through digital human modeling software, we are creating the first level of characterization of virtual avatar. Then, acquired stumps MRI. From stumps MRI, that MRI data, second level of characterization takes place for the avatar or virtual digital human model. So, first digital human model is created as per anthropometric data; second, it is modified as per the information for the stump body part; then, third level of characterization of the avatar with prosthesis.

This prosthesis comes from prosthesis modeling lab. To select standard parts and assemble prosthesis, that is the 3D CAD system. From 3D CAD system those standard prosthetic, assembled prosthetic parts come and it is attached with the digital human model. Then, static alignment and gate analysis are performed. If everything goes correct; if the prosthesis if it is found following the gate analysis and analysis in terms of alignment; if it is found that, everything is right; then, it is go for manufacturing or production; means prosthesis is validated, then it can be used. If it is performed this analysis, if it is found, now that prosthesis is not designed properly; then, again there is modification of the socket model and modification or changing the selection of the standard parts from the parsed database. So, in this way, prosthesis modeling lab and virtual lab actually helps in developing the prosthesis prosthetically for the amputee.

So, this is the digital human model. So, if there is upper leg amputee, then this is the first digital human model is created through this. In this case as we mentioned, we used this in this LifeMOD software with that AnyBody software, yes. So, with this AnyBody digital human modeling software, this is the initial human model. Then, when there is amputee case, then this is for upper limb, upper leg amputee and this is for lower leg amputee, this model is created. Then, with that model that based on the MRI scan stump body parts that is, the residual portion of the bone is identified and it is attached with that model. Similarly, this is for lower limb amputee. In that case also, stump body part is attached. Then, there is attachment of the soft tissue in case of upper leg amputee as well as for the lower leg amputee. After that, the prosthetic or prosthesis is attached with the socket. Similarly, in this case also, prosthesis is attached with the digital human model. Then, the final model becomes ready for both the upper leg amputee as well as lower leg amputee.

When this final human model with prosthesis is ready for both the cases, that is, transfumeral model as well as for transtibial model, when both are ready then these are used for movement analysis and alignment analysis, that is, gate analysis as well as the alignment analysis; whether this prosthesis is aligned properly with the in relation to other leg. To create and simulate the patient’s virtual human LifeMOD software was used. So, in this digital human model, which has been used in this particular case; that is the LifeMOD software.

Virtual testing, an avatar of the patient wearing the prosthesis is created by which it is possible to execute prosthesis setup and evaluate its functionality, simulating posture and movements. Two test cases have been considered: a transtibial amputee that is 35 years old, 170 centimeter tall and a transfumeral amputee 49 years old and 175 centimeter tall. So, as we mentioned this is the example of the transfumeral model, how it is developed. And similarly, this is the transtibial model how step by step it was developed.

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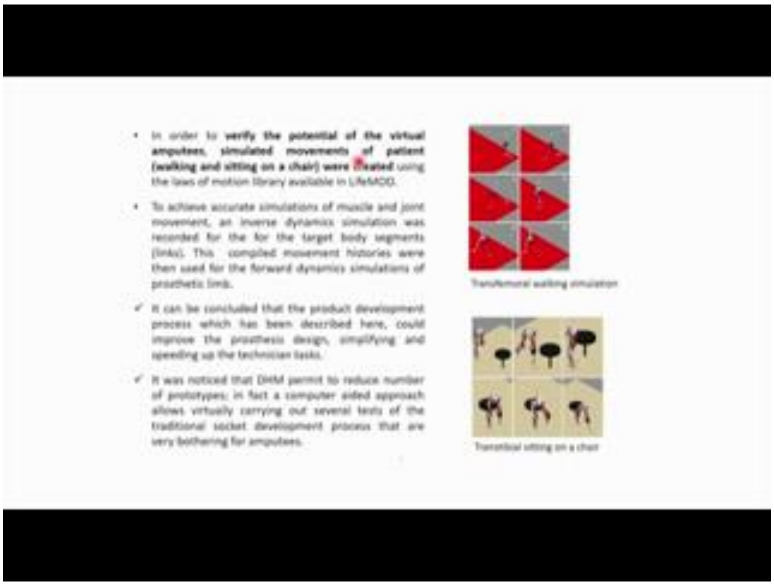


In order to verify the potential of virtual amputees, simulated movement of the patient that is working and sitting on a chair were created using the law of motion library available in LifeMOD software. To achieve accurate simulation of the muscle and joint movement, an inverse dynamic simulation was recorded for the target body segments, that is, the links. These combined movement histories were then used for the forward dynamic simulation of the prosthesis link. So first, for inverse dynamic simulation was recorded for the right limb and from that limb the compiled movement histories of the dynamic motion were compiled and used for forward dynamic simulation of the prosthetic limb. It can be concluded that, the product development process, which has been described here could improve the prosthesis design simplifying and speeding up the technician task.

So, earlier what we used to do; technician has to go for trial and error method; and in that case, there was bothering of the patient because that, this type of socket has been designed by trial and error method by the technician. Then, it is attached with the human body; then, different types of trials are performed with the real human subject. But, as the whole prosthesis design as described in this image, the whole prosthesis design method is being performed in the virtual environment. So, it is very much helpful for the technician to find out the right or correct prosthesis design and also it is possible to analyze how whether the designed prosthesis limb will be effective for normal movement of the patient.

It was, here from this image, you can see transfumeral walking simulation, which this author performed and also transtibial sitting on a chair. So, both the task: one is walking another is sitting task was simulated in LifeMOD software and that prosthetic assembly was tested and then it was understood that, these prosthetic organ or prosthetic parts can be used by the patient. It was noticed that, digital human model permits to reduce number of prototypes. In fact, a computer aided approach allows virtually carrying out several tests of the traditional socket development process; that are very bothering for the amputees. So, from this research paper, it is very evident that digital human modeling software can effectively be used for the overall development process of the prosthetic limb or prosthetic assembled parts.

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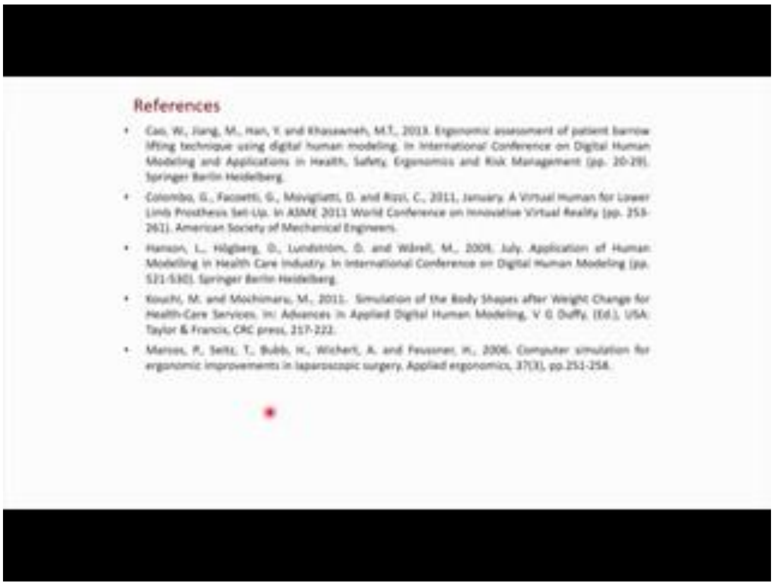


And, here are the various references, which have been used for these various slides of the presentation. So, in this particular section, where we are discussing about the use of digital human modeling for healthcare application, only few research papers we have discussed here. But, there is thousands of research paper reported by various researchers. So, I suggest all the students, who are undertaking this course, please go through all these as many as papers you can read to understand that, how this digital human modeling software are nowadays being used for healthcare education, healthcare practice, healthcare workstation design. And, then only you will be able to use digital human modeling software effectively for your own design purposes.

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After discussing this healthcare industry, now, in the next section, in the consecutive slides, we will discuss about how this digital human modeling software are being used by various researchers for general industrial applications. Design of industrial workstation has been revised based on study characteristics analysis and evaluation tools, modeling approaches and results achieved. So, this was reported by Lango and Montril in 2011. Simulator 2009 described evaluation of industrial plant layout considering 8 workstations, 14 workers, who are involved in making high pressure hydraulic hoses. So, these are the few images from different research papers, where digital human modeling software has been used either for factory layout or manual material handling, product evaluation, user interface evaluation; or, in various cases, this digital human modeling software has been used.

Manual material handling and user interface evaluation are evaluated using method time measurement was working analysis system, lift analysis in eM workspace software. It was reported by Santos et al. 2007. Biomechanical analysis was also done with the own developed model, that is, SIMM having scalable human model, motion capture, inverse and forward kinematics. So, this was reported by Okimoto in 2011. So, from this slide, we can get overall idea that, various researchers were using digital human modeling software for industrial workstation or for different types of activities performed in those industries.

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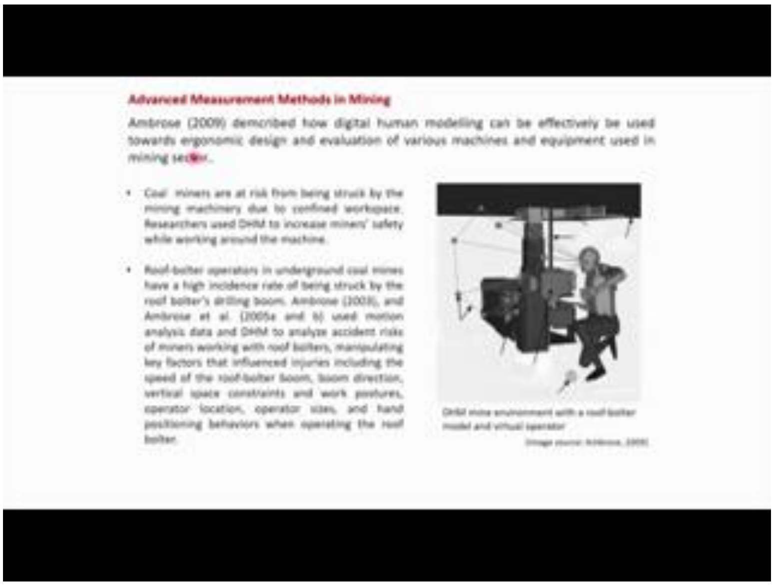


So, in that research in a book chapter written by Ambrose 2009, the title of the book chapter is advanced measurement method in mining. In that book chapter Ambrose et al; Ambrose described how digital human modeling can be effectively be used towards ergonomic design and evaluation of various machines and equipment used in mining sector. Coal miners are at risk from being stuck by mining machinery due to confined workspace. Researchers used digital human model to increase miners' safety while working around the machines. Roof bolter operators in underground coal mines have a high incidence rate of being struck by the roof bolder drilling boom.

Ambrose 2003 and Ambrose et al. 2005 in those reported literatures, it is found that, they used motion analysis data and digital human model to analyze accident risk of miners' working with roof bolters manipulating key factors that influenced injuries including the speed of the roof bolter boom direction, vertical space constants and work postures, operator location, operator size and hand positioning behaviors when operating the roof bolters. So, here from this image it is shown that digital human model while they are using that roof bolter; then how is their posture and what type of activities they performed.

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Eger et al. used an observation zone and coverage plane features in a digital human modeling software which is an effective tool for evaluating line of sight of the earth movers, yielding better understanding of the underground machine design. Ambrose et al. 2004 effectively used digital human model to evaluate severity of muscle recruitment and spinal load while operating a roof bolter in different work postures and mine steam heights. They generated a database containing L 4, L 5 spinal joint and back muscles by processing captured motion from test subject using digital human model. Their study results showed that, operator's forward bending moment increased significantly from a standing posture while the compression force and trunk muscle activity were greater from in comparison to kneeling posture. So, from this image you can see while the kneeling posture, workers are working in kneeling posture that is relatively better instead of this standing posture, because in standing posture, the bending is more. As the bending is more, there is more compression at or intervertebral discompression at L 4, L 5 segment.

Bartels et al. 2007 applied digital human model vision tool and survey data to define the value attention location. Their observations provided preliminary recommendation for control observations that enhance VAL means value attention location enhancing safety and reducing health risk of mining equipment operators.

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In the research paper, Case et al. 2009 entitled HADRIAN fitting, that is the name of the software; HADRIAN fitting trials by digital human modeling. In this paper, Case et al. described about the HADRIAN, a digital human modeling system, which uses discrete data set for individual rather than the statistical population. So, in this digital human modeling software, instead of statistical population, they used discrete data set of the individual anthropometric dimensions. They also demonstrated the application of system with a focus on elderly and disabled and their potential exclusion from public transportation systems. HADRIAN system provides two important ergonomic aspects: that is, use of individual set rather than the population statistics such as percentiles of anthropometric and other data had means of describing the interaction with the product. So, in this HADRIAN software, two important aspects are considered that instead of using percentile anthropometric data, they used the individual data set of the targeted population, and at the same time they described the interaction between human and the product through task description process.

The data collected from the earlier study pertaining to anthropometry, joint constraints, reach and mobility of aged and disabled people were used in the present research to represent the target population. This is a screenshot from that HADRIAN system; examples of various windows for specific individual in the HADRIAN database. So, for movement of the body joints, then clean video then clips of the task performed by the actual person, reach envelope. So, various aspects are shown in this particular screen.

And, the data collected from a population of aged and the disabled people. So, this is that representation, where various types of members are there with the various types of capabilities and physical dimension. And, this database was actually used for their demonstration purpose that, how individual body dimensions or individual capability, work capabilities is actually affecting in performing various types of task.

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HADRIAN contains the database of individual and task description method to execute the evaluative capabilities of underlying SAMME human modeling system, as though a real fitting time was being conducted. The task and its evaluation criteria are defined using a simple task description language. And, the subsequent analysis uses this task description to create and drive a human model to evaluate their capability in performing the task. So, this is the task description screen. So, various types of tasks for a particular activity can be defined using this task analysis window of the HADRIAN software.

On completion of the task analysis, the percentage of the individual of the integrated database; and from that integrated database, the percentage of the individuals who can perform that particular activity is actually estimated. If there is person or people, who are unable to perform that particular activity as defined by this task description language, if it is found that, the database which was considered; some people of the database cannot perform that activity; then, those people will be identified. At the same time, not only identification of those people, who are unable to perform those activities; at the same time the system will also identify and the situation which causing difficulty will be displayed with the suggestion for improvement. So, who are the people who kind of perform that activity and why they kind of perform that activity that will be displayed.

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In the current research paper, capabilities of the HADRIAN system has been demonstrated with the case example of ATM machine operation and accessibility aspect of the public transportation system. These two case examples were taken into consideration. Potential barriers faced by the people during performing various activities of travel can easily be identified by this HADRIAN system. From the database, can be during who making these journeys are being identified. So, potential barriers faced by the people are identified and accordingly we can modify the system or the facilities, so that most of the people, who are facing the problem, can overcome those problems. HADRIAN task description capabilities allow the modeling system to be used as an automated evaluation tool. Moreover it allows for the consideration of issues beyond the physical aspects of anthropometry.

So, in this particular research paper, where Case et al. 2009 through this HADRIAN system, they demonstrated that it is not always possible or not feasible to use percentile anthropometric data, because there are many situations, where we cannot evaluate the product with percentile, because there are many situations; while there is no good correlation between different anthropometric dimensions, then we cannot use percentile anthropometric data for digital human modeling development. And, this is very much applicable for aged and disabled population.

So, for them, if we want to design or if we want to evaluate any facility or any workplace, then we need to use this type of HADRIAN software, where a specific database is used. In that database, instead of use percentile anthropometric data, individual set of anthropometric data of the persons are used. And, their various tasks is defined through task description language. And, for each of the individual, the task is performed. And, from that analysis, ultimately we can identify how many of those people can perform that particular task and how many of them cannot, and who cannot perform that activity, then which can find out that what is the reason behind that.