Digital Human Modeling and Simulation for Virtual Ergonomics Evaluation
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Lecture – 23
Future research avenues and steps to be taken towards widespread Part III

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After discussing about various limitation of digital human modeling software, and how we can adopt this digital human modeling technology, what are the steps to be taken for wide adoption in developing countries, we have already discussed. Now we are going to discuss future research scope in the field of digital human modeling. In the coming few slides, we will discuss about opinion or few of various researchers, what they mention about the future scope of the digital human modeling software.

Many of this references mentioned here are old and as this are the old references so many of the future research scope mentioned by those researchers are right now actually not future research scope those are already been adjust.

Apart from that there are still there are so many aspects which are needed to be adjust in the while we are going to develop digital human modeling software, or while we are thinking about new application of digital human modeling software so first we want to mention the opinion of Balder 1997 projected, he projected that the achievement sorry the advance advancement of virtual humans will help in presenting information through

training aids virtual experiences and even teaching and mentoring. He also predicted that virtual humans will help to save lives by providing surrogates for medical training surgical planning and remote telemedicine. Now in 2016 if we look at, various digital human modeling softwares available in the market then we find many of these issues have already been adjust.

Now, digital human modeling software or full digital anatomy of human body is already been created. And those are being used for medical training surgical planning and telemedicine. This type of physiological human model is also being used for medical training, training of the nurses as we have also seen in or earlier discussion while we are discussing about application of digital human modeling software in health care industry. Beagley 2000 proposed that digital human modeling tools need to automate fine control of the manikins, with options of manual override by the user.

At any point or at any level, mean digital human modeling software or it is capability should be automated, but there should be some option so that as per our requirement or user requirement we can override those automatic features. For example, DHM should know he mentioned in this way that DHM should know how to sit on the on a particular seat or chair. Then how to use a display so those option should be there what is needed by the by the computer is to take on the labor intensive task of manikin control to free up human effort to consider the information provided by the tool.

So, it means, that the human the computer should be capable for the digital human modeling software should be capable or it must have that capability so that we can easily position the digital human manikin, on the particular work station or we can interface in particular product. For that purpose, lot for much effort should not be required. On the other hand, while human is or user is free or why users are not engaged in this task labor intensive task for manually positioning digital human manikin, on the respective seats or work station.

Then he will he or she will be free to process the information provided by the various analysis can be performed, but otherwise what happens users explain most of the time, for proper positioning proper interfacing of the digital human model with the work station or product model so if that can be done automatically or very easily than it will be very user friendly. He also proposed to improve the reliability and consistency of the

digital human. Models enhancement of the model of human performance in the synthetic environment, is one of the area for future research current evaluations require the expert to make a judgment of the users' ability to operate in an environment for a prolonged period.

So, at the situation, right now the digital human models, they are not capable of simulating the effect of environment, while people are in that environment or in that work place for a prolonged period so in future so right now so as he mentioned current evaluation require expert so expert or who are using the digital human model software. He or she has to make the decision that what should be the effect while that environment or that work station is been used by a person for the longer duration.

Models of attention and information processing capacity could be used to highlight the features of design, which might lead to insupportable load under situation of high activity, or likelihood of error during period of low activity so model of intend attention and information processing capability could be used. Because right now this type of capabilities is still lacking so this will be very much helpful.

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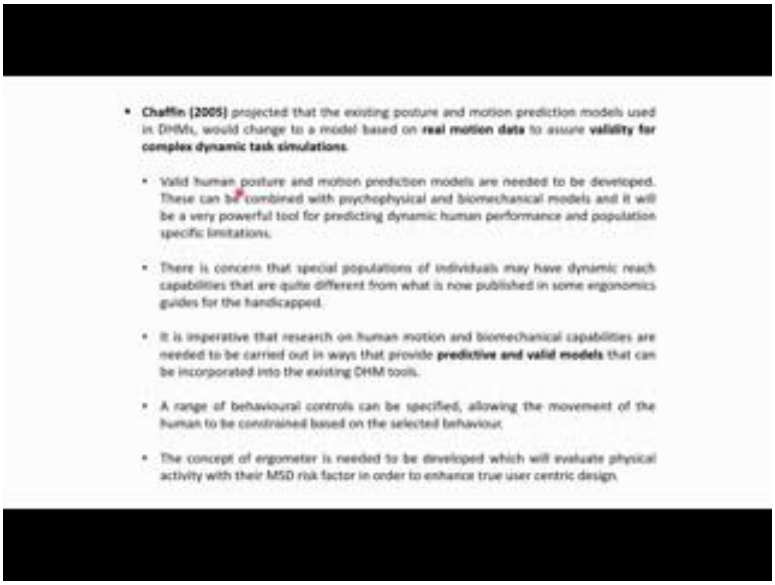

Chaffin 2005, projected that the existing posture and motion prediction models in digital human models would change the model based on real motion data? Would change to a model? So right now in 2005 by Chaffin mentioned many of the digital human modeling softwares are using inverse kinematic model so he mentioned that this model should be

changed to a model based on real motion data; to assure validity for complex dynamic task simulation. Valid human posture and motion prediction models are needed to be developed. These can be combined with psychological and bio mechanical model and it will be a very powerful tool for predicting dynamic human performance and population specific limitations.

So, he very rightly mentioned that, real human motion data, which can be captured through 3D motion analysis system so that human motion data can be incorporated in this type of software, not only motion capture data along with that, if it is possible to incorporate physiological data bio mechanical model. Then it will be a powerful tool for predicting dynamic human performance. And also for population specific limitation, because from population to population range of motion varies population to population their force capabilities varies. So this is very important.

There is concern that special population or individuals may have dynamic reach capabilities that are quite different, from what now published. What is now published in some ergonomics guide for the handicapped so for special population not only for physically challenged person, but even for population to population the reach capability as I mentioned earlier the range of motion for particular body joints force capabilities it also varies.

Not only from population to population, from individual to individual, in the same population it also varies. So these types of issues to be adjust while we are further developing digital human models. It is imperative that the research on human motion and biomechanical capabilities are needed to be carried out in the, carried out in 2 ways, that provide predictive and valid models, that can be incorporated in to existing digital human models so predictive and valid models are needed to be incorporated in the existing digital human model tools.

A range of behavioral controls can be specified allowing the movement of the human to be constrained based on the selected behaviors so human motions based on the selected behavior are needed to be incorporated. The concept of ergometer indeed is the concept of ergometer is needed to be developed which will evaluate physical activity, with the musculoskeletal disorder risk disorder risk factors, in order to enhance the user centric design.

So, in this digital human modeling software, if ergometer concepts can be incorporated, which can apart from posture evaluation, which can calculate the energy expenditure and many other aspect so that while we are evaluating any place any work station or work place with digital human modeling software, then during that physical activity evaluation we can also understand what would be the risk for musculoskeletal disorder. And thus in this way we can make the work station more user centric.

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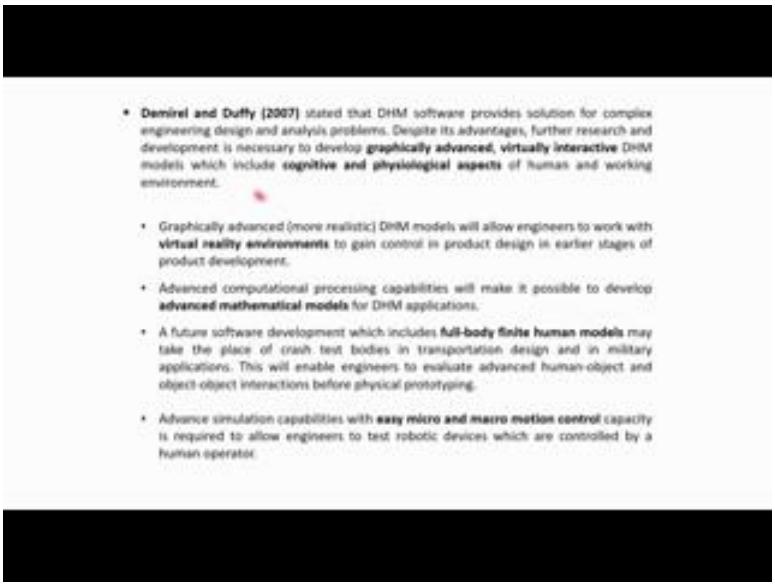

Demiral and Duffy 2007 stated that digital human model software provides solution for complex engineering design and analysis problem. Despite it is advantage, despite it is advantages further research and development is necessary to develop graphically advanced virtually interactive digital human models, which include cognitive and physiological aspects so not only physical aspect so in future research more cognitive and psychological aspects physiological aspects are needed to be considered for human model working of human and working environment.

Graphically advanced mean more realistic digital human models will allow engineers, to work in virtual reality environments to gain control in product design, in earlier stages of product development so they are highlighted, that is graphically advanced digital human models is need to be used in virtual reality environment to gain control in the product design in earlier design development stage. Advanced computational processing capabilities will make it possible to develop advanced mathematical models for digital

human model applications. A future development which includes, full body finite human models, may take the place of crash test bodies in transportation design so they also proposed that there is requirement of full body finite human models, which can be used for crash testing, in transportation design and in military applications.

This will enables engineers to evaluate advanced human object, and object to object interaction, before physical prototyping advance simulation capabilities with easy micro and macro motion control capabilities is required, to allow engineers to test robotic devices which are controlled by human operator so in this way various aspects are been mentioned by Demiral and Duffy in 2007, that this aspects can further way adjust so that digital human modeling software, can be improved, in it is capabilities. And it can overcome it is existing limitations.

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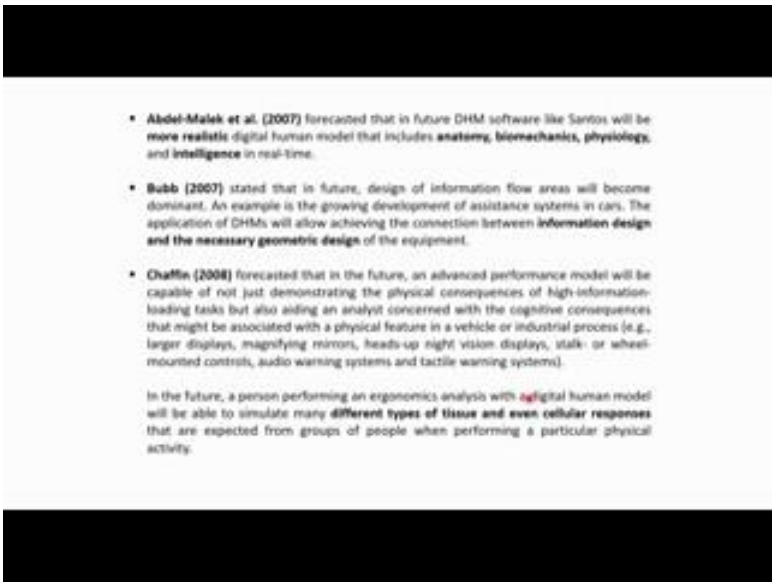

Abdel Malek et al 2007, forecasted that in future, digital human model softwares like Santos will be more realistic digital human model, that includes anatomy biomechanics, physiology, and intelligence in real time so he forecasted that, during their development of Santos software under virtual research virtual soldier research initiative, they mentioned that in Santos software, they are planning to incorporate all this features, in 2007, and many of this features are already been incorporated now in 2016.

Bubb 2007 stated that in future design of information flow areas will become dominant. An example in this growing development of assistance system in cars .the application of

digital human models will allow achieving the connection between inter information design and the necessity of geometric design of the equipment so as the information processing, information flow are becoming more important in present day scenario.

So Bubb et al Bubb in 2007, he proposed that the application of digital human modeling software must have that capability so that it can, we can achieve the connection between information design and necessary geometric design so how the information to be project presented on the displays and accordingly what should be the geometric design of that equipment or display we can determine by using digital human modeling software. Based on the viewing distance viewing angle a so many other aspects and this will be very much applicable in automobile industry.

Chaffin 2008 forecasted that in future, an advanced performance model will be capable of not just demonstrating the physical consequences, of high information loading task, but also aiding an analyst concerned with the cognitive consequences. That might be associated with a physical feature, in a vehicle or industrial process. As for example, larger displays, magnifying mirrors, head up, night head up display, night vision display, stalk or wheel mounted controls, audio warning system, tactile warning system and. So on.

So, Chaffin 2008, they mentioned not only physical consequences, but also we need to consider the cognitive consequences, which are associated with many of this task. In future a person performing an ergonomics analysis, with digital human model will be able to simulate. Many different types of tissue and even cellular responses that are expected from group of people when performing a particular physical activity so they also proposed that research is required in this direction so that in future we can simulate this type of tissue and cellular responses.

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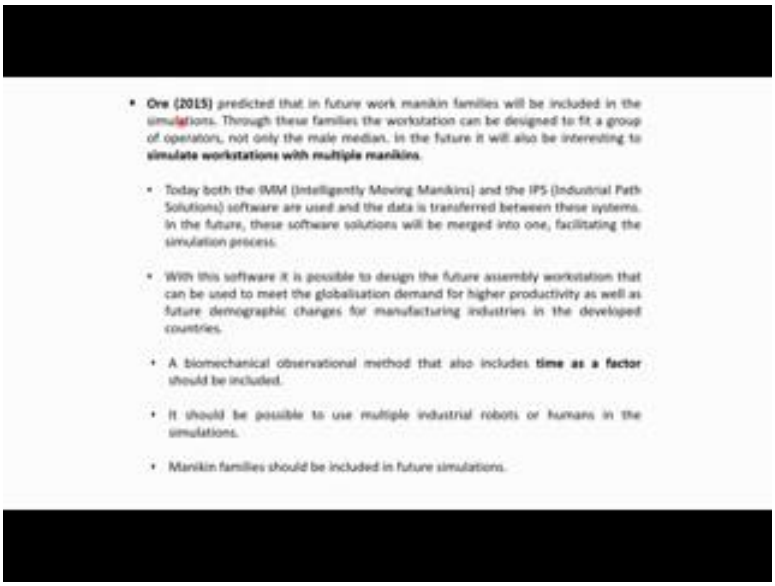

Ore 2015 predicted that in future, in future work manikin families will be included in the simulation. Through these families the work station can be designed to fit a group of operators, not only for male median, because in many places you will find that researchers only use 50th percentile digital human model for evaluating their work station. In future it will be interesting to simulate work station with multiple manikins so for a single work station that this softwares must have that capabilities so that we can go for evaluation on multiple manikins simultaneously.

Today both IIM mean IMM intelligently moving manikins, and IPS industrial path solution softwares, are used and the data is transferred between these systems. In the future these software solutions will be merged in to one facilitating simulation process so he proposed that merging of this 2 software are required, for further advancement or virtual ergonomic evaluation process. With this software it is possible to design the future assembly work station that can be used to meet the globalization demand for higher productivity as well as future demographic changes, for manufacturing industries in the developed countries.

A biomechanical observe observational method that also include a time factor should be included so while we are thinking about the biomechanical evaluation, then not only body joint angle or muscle activity is needed to be evaluated at the same time, we need to consider the time factor. It should be possible to use multiple industrial robots or

human in the simulations. Manikin families should be included in future solution so we will discuss more about these manikin families.

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Johnson and Fletcher 2015 predicted that the user input can be gained through the use of virtual reality and mock ups to identify physical usability. And ease of access for structures along with qualitative comfort data.

While we are evaluating with digital human modeling software, then we are mainly getting the quantitative data based on that analysis, but we cannot go for subject evaluation or subjective liking ness disliking ness all this and their comfort, their perception about the comfort so for this purpose Johnson and Fletcher 2015 predicted that, that if we can use input in digital human modeling software, we can if we can take input from virtual reality, and mock up study to identify the physical usability, and ease of access of structures along with qualitative comfort data.

So, apart from digital human modeling software, what we can do we can create physical mock up and through virtual reality system, we can get the real users feedback, and based on that we can evaluate the work station, or model, product model. This information can be used to improve the design, and help to mitigate the work related injuries, and stress helping reduce the cost relating to injuries and improve work performance.

Nerot et al 2015, assessed 2 digital human modeling systems, widely used in industry for virtual ergonomics. Results supported the need of a more realistic human modeling especially for biomechanical analysis and standardization of DHM so another important aspect related to DHM is the standardization. Because from software to software the result varies so standardization is very important.

This study opened the way of further research on the relationship, between external body parameters landmarks measures etcetera, and internal skeleton on in order to reduce the errors in joint location so and improve the realism of current digital manikins so generally while we are even going for motion capture, we are placing the marker on the external surface of the body.

And that actually there is error in recording the actual movements of the joints, because we are unable to place the marker on the joints there is difference of positioning the relationship between external body parameters like so this is needed to be established that is what the exact relation between the external body parameters or external landmarks and internal skeleton in order to remove or reduce the errors in joint location and consequent movement of the body joints.

And if we can establish this relationship between this two, that is the external body parameters or external landmarks and internal skeleton landmark then it will be easy to it will be more the human it will improve the realism of current digital human manikins. This study also reveals that the gap between the relationship of external body geometry and internal skeleton is to be addressed, in order to improve the realism of current digital manikins, skeletal model; specifically, for a biomechanical analysis requiring information of joint load and muscle force estimation.

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Now, after discussing so many issues o so many future research directions by various researchers, now we are going to discuss another 2 reported literature information, where the researchers are actually giving future research scope of application of digital human modeling software. In many a times we find that application of digital human modeling software in a particular industry that mean automobile industry or aerospace industry or agricultural sector it is, it is application is limited.

Sometimes say for example, Sanjog et al 2015, during their review on application of digital human model, in aviation and aerospace industries, mentioned that presently applications are only limited or only confined to few aspects or aviation and aerospace industry. For example, many of the applications we can found find in the area of cockpit design passenger seat design or accommodation in the space craft maintenance application, but there are so many other aspects, so many other areas where this digital human modeling software can actually be used for evaluating those facilities.

They proposed the use of digital human modeling software in for the ergonomic evaluation of ground activities of aviation and aerospace industry. Like security check reception services afforded to passengers including those of special needs passenger baggage loading and unloading from aircrafts, and retrieved luggage delivery and bulk cargo handling ferrying of passengers from and through aircraft, and on board passenger service air traffic control parking and so many other areas.

So, Sanjog et al in their paper research review paper, they tried to show that although application of digital human modeling in aviation and aerospace industry is going on for longer duration, or it started from long back, but again there are enough scope of application of this software or evaluating various other work station or other facilities. Because only people are concentrating in few areas of application, but there are so many other areas or this digital human software can be used effectively.

Similarly, Patel et al in 2000, in their review paper mentioned that, digital human modeling software in agricultural sectors are mainly confined to design and development of agricultural tractor or vehicle, but there are so many other areas. Like design of hand tools, design of storage space then, tools and equipment design related to plantation harvesting, post harvesting storage food processing so in this areas, there are still scope of use of digital human modeling software for achieving better man machine field or man machine compatibility.

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Now, after studying these earlier slides, now we can summarize that what are the areas where digital human modeling software can be used, or how we can improve digital human modeling softwares capabilities to address various lucky.

So, as it is observed that simultaneous analysis, and activities of multiple manikins, are not possible in any of this software so there is, need there is a need to address this issue so that simultaneously we can evaluate multiple manikins activity. In an industrial work

place or how there is an assembly work are so many workers, are working together. Then simultaneously we need to evaluate their activities in terms of various ergonomics aspects, like their posture, their posture evaluation, their muscle force, their comfort discomfort. So all these aspects there should be provision in those digital human modeling software so that we can measure all these aspects simultaneously for more number of multiple manikins, not for a single manikin, which is presently available, but we need to go for evaluations of all this aspect for multiple manikins simultaneously.

Next important aspect is multi various statistical approach to generate boundary forms retrained in the target population, so for many of the software and also for many of the application, we find that researchers are using statistical model, statistical manikin a 5th 50th or 95th percentile manikin.

While they are using those manikin of percentile values, specific percentile starting from 5th to 95th, many a times it is not possible to accommodate the expected range of population, while they are using researchers are using 5th percentile manikin and 95th percentile manikin, and they are expecting that 95 percent of the populations are included in that design, but actually it is not possible there are many reason.

First, the body dimensions are not perfectly correlated with one and other. And thus there will be different people may be outside this range, from 5th percentile to 95th percentile. Because many one or more body dimension of a particular individual may be outside this 5th percentile to 95th percentile range, and for that reason they will be excluded. And if we check the how many percentage of the population, or how much percentile of the population is excluded, then we will find that is a good amount.

So for that purpose not only this is the reason, another reason is in reality there is now, it is not possible to have on one single individual, because all body dimension is of a particular percentile value. Uniformly large and uniformly small models do not necessarily describe the engineers' worst case scenario. For that what happens combination of extremely large or extremely small values in the same subject, may be critical or designing any facility.

Next, model created from percentile segments are unrealistic in terms of size in terms of shape. So for that purpose researchers adopted a new technique that is multivariate statistical approach. So with this approach for this multivariate statistical analysis, we

can go for principle component analysis. With the principle component analysis what we can exact exactly do, from a large number of anthropometric variables or biomechanical variables, we can identify a small group of anthropometric or biomechanical variables, which actually describe the larger portion of the overall variation created by large set of anthropometric or biomechanical variables.

So by this statistic multivariate statistical analysis like principle component analysis, we can actually identify a small group of variables which will represent the overall variation in the population, and through this multivariate statistical approach creating boundary manikins we can accommodate a large portion of the population. And this boundary manikins will actually represent the combination of small or and larger body dimension.

So from this set of small set of boundary manikins, we will be able to represent various combination of larger and smaller body dimension and while we are evaluating any product facility or work station with this type of group of manikins, which is actually representing the boundary forms then we will be able to accommodate a wide range of population.

So, for this reason although initially, many of this digital human modeling software used percentile manikin, but nowadays it is going to shift towards boundary manikin approach. And through this boundary manikin approach we can accommodate large numbers of people for a product facility. Subjective evaluation for the product and work station design, it is also important because right now all this evaluation is based on objective measurement by digital human modeling software, but what is the subject's opinion, while he is working in a particular work environment.

For example, we are going to evaluate a product, while there is while we need to evaluate the form of the product or color or appearance or aesthetic then those types of things right now we cannot evaluate with digital human modeling software. So for this purpose subjective evaluation is required. So this is the area where digital human modeling software is further needed to be developed, so that various subjective issues can be addressed.

Already in the earlier slides we have seen that many researchers are proposed that for this purpose we can use virtual reality, where real human can interact with the virtual environment and they can give their feedback, while they are using the mock up. And in

this way we can reduce the cost of the actual product development. Moreover, for this subjective evaluation and for many other cognitive aspects measure or determining the cognitive work load for a particular task, so this cognitive aspects are needed to be further research for development of digital human modeling software.

Then realistic human appearance and behavioral aspects are needed to be adjusted. For many of the digital human modeling software that human movements are robot life or it is an appearance also robot life. So these human models are needed to be developed in such a way it looks like real human, with real skin deformation muscular muscle structure, and be it is movements it is behavior could also mimic the real human behavioral or real human motion impact of environmental factors of human performance and efficiency.

So with most of the presently avail, presently available digital human modeling software the impact of environment on human performance and efficiency is not been assessed, so further research is required in this direction so that in future we can use digital human modeling software for evaluation of environmental aspects, like effect of temperature humidity or illumination on human performances efficiency. Then comfort discomfort analysis whatever is possible with the present digital human modeling software are mainly based on human body joint angles.

So based on the human body joint angles, whether those body various body joint joints are within the comfort range of motion or not based on that we can evaluate the human comfort, but this are momentary observation in that particular movement, how is the body joint angles and based on that we are taking the decision about the whether the human posture is within comfort zone or not.

But while in the particular posture although it is comfortable, but while individual is adopting that posture for longer duration. Then how will be his feeling or her feeling and how will be the effect of time on a constant posture, that type of evaluation is not possible with present digital human modeling software. So in this direction further research is required so that the comfort perception of with longer time duration can also be assessed. Effect of age on mobility field of view is needed to be explored.

So, for this purpose, database is needed to be developed, on based on joint mobility field of view, with the changes of age or advancement of age for human beings. Apart from

this there is also requirement for developing the view vision analysis tool regarding the color vision, or different color spectrum. How people will how the how much area people will be able to visualize. So those aspects are further needed to be developed. Integration of digital human models with immersive virtual reality system, to enable real users to not only interacts with the virtual environment, but also with virtual human. So there is also requirement of integrating immersive virtual reality system, with the digital human modeling system, so that the real user can interact not only with the virtual environment, but also the virtual humans, in those virtual environments.

Then further research is also require in the direction of clothing and personal protective equipment for proper clothing we need to study the interaction of or interference of the clothing with the human body segment clothing or inter interference between 2 parts of the clothing.

Similarly, for proper fitting of the protective equipment with human body parts those are also very important, and further research is still required in this direction for achieving optimal clothing design and personal protective equipment design. Then modeling of physiological aspects of digital human modeling is further needed to be developed. Many of these issues have already being addressed.

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Or are already being addressed in advanced digital human modeling, softwares like Santos and it was developed by being developed I mean still advance development is

going on, under virtual soldier research program at university of Iowa. Other commercially available digital human modeling softwares are lagging behind in this regard.

So hence there is in near future more research is needed to address in all the above mentioned issues to make the digital human model as the representative of real human, so as in this section it is clearly mention that many of this aspects are been adjust by Santos software developed by Iowa university, so for other software this are needed to be adjust, only few of the commercially available softwares are addressing this issues, but for most of the digital human modeling software this issues are needed to be adjust.

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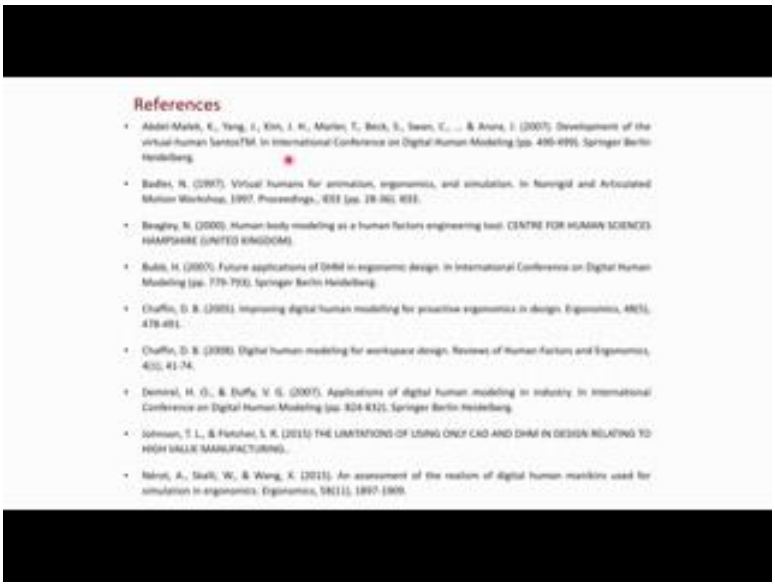

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So, this are the references, from this references various future research direction, I have been obtained. Now particularly they want to highlight the virtual soldier research and how they have developed digital human modeling software that is the Santos.

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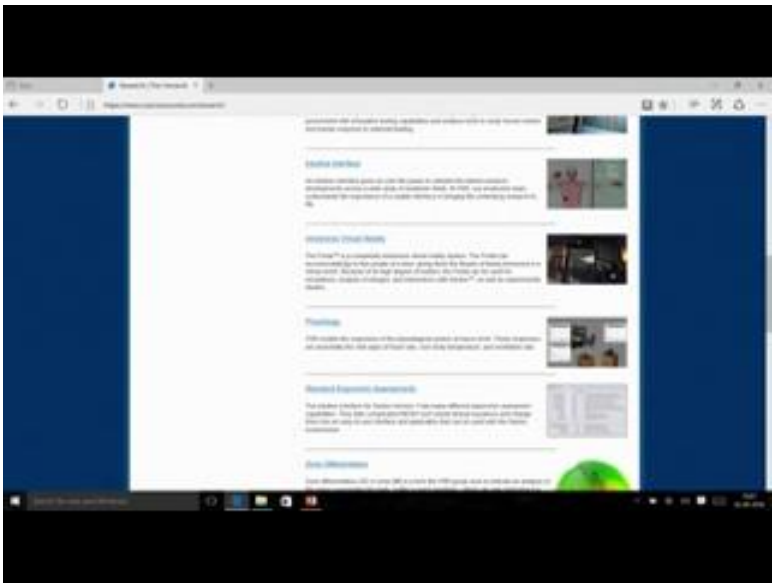

So, for this purpose we will go to the site, so this is that web page of virtual solder research at university of Iowa, so you can see so if you look at their web page then you will understand what type of research is going on there. So they are developing musculoskeletal model, full body vibration model. So 3D bio motion research lab they

are developing this whole body vibration model. Then various types of validation they have already incorporated motion capture system, so that they can directly incorporate real human motion data in to digital human models.

Then in to it interfaces then immersive virtual reality, they have already collaborated with another system of immersive virtual reality and they have incorporated the digital their Santos digital human model in that immersive virtual reality environment. So the as they have mentioned the portal, is a completely immersive virtual reality system. The portal can accommodate up to 5 people at a time, giving them the illusion of being immersed in the virtual world.

Then there is physiological modeling, various physiological aspects are being model. They have already developed metabolic energy expenditure calculation of metabolic energy expenditure, during particular work and based on that energy expenditure. They have converted that in this expenditure, to the equivalent oxygen. That how much oxygen is being consume to, to produce that much energy, and from that oxygen consumption they again calculated the heart rate core body temperature respiratory rate. So in this way in the Santos digital human modeling software we can also evaluate the energy expenditure, oxygen consumption, and based on that oxygen consumption heart rate core body temperature with rate of ventilation etcetera.

Similarly, various types of standard ergonomics assessments are possible there. Then zone differentiation posture, and motion prediction, they have already developed for, for predicting motion. They are using physics based forward dynamics. So they have already researches, are going in that direction. The heavy so if you see here the ability to carrying posture and motion realistically is the task and any comprehensive effort to model humans. So they have developed extensive capabilities in this areas using optimization.

Then for SPI, they have also performing research in the field of spine modeling, and then gait analysis predictive dynamics. Predictive dynamic is term point to category characterizing the prediction of human motion in physics based world. So they have developed this predictive dynamics, to predict the human motion. Then again they have gone for modeling of clothing, realistic modeling then human performance modeling, armor and soldier performance. So if so you can explore all this side for various advance

aspects of digital human modeling software, and in which direction present researches going on.

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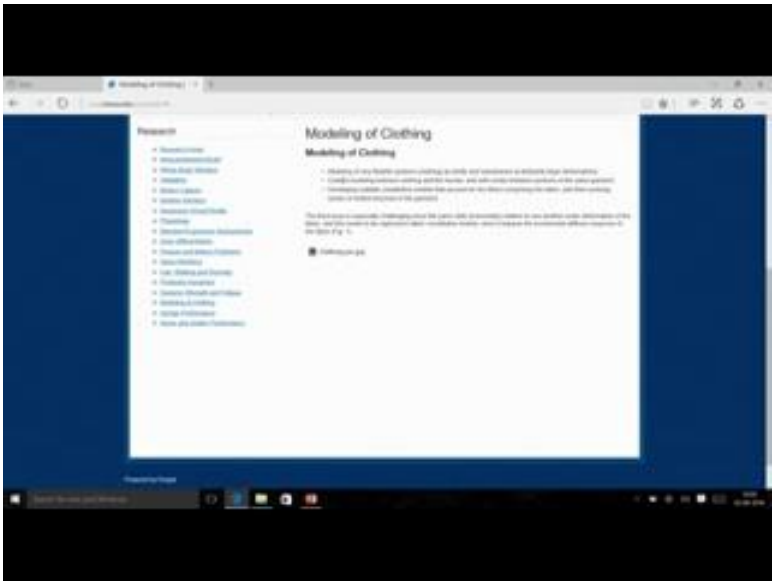

So, if we look at this say advanced modeling of clothing, then you will find the presently they are doing research in the field of modeling of very flexible system clothing. Then contact modeling between clothing and human and self-contact between portions, of the same garment then developing suitable constitutive, they are also developing suitable constitutive models, that account for fibers comprising the fabric and their evolving woven or knitted structure in the garment. So in this various aspects, they are virtual soldier research you for developing the Santos software for clothing modeling this various aspect are being adjust.

So, there it is mentioned these 3 points flexible system, they are developing, then contact modeling and also they are thinking about or they are addressing the suitable constitutive models of fiber interaction, for the clothing. So here you can see all these research areas so for further exploration, you can click in click on all these menus and you can get clear picture that presently in virtual soldier research, what type of research is going on for advancement of digital human modeling.

Similarly, this I gave the example of Santos software. Similarly, for other softwares also, you can explore for Jack Sami Rumsis. So you can explore individual softwares to

understand what type of future research reaction they have taken, and they are proceeding so that is all.

Thank you.