Digital Human Modeling and Simulation for Virtual Ergonomics Evaluation

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Lecture – 22
Future research avenues and steps to be taken towards widespread Part II

After discussing about application of digital human modules in different industries, now we are going to discuss digital human modeling in industrially developed countries.

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In industrially developing countries, it is found that digital human model link and simulation is not that much popular and its application are very limited. So, why this digital human modeling software, is not that much popular or what is the reason behind this less adoption of this technology. Developed countries are widely using digital human model technology for manifold applications, and have realized immense benefit.

The use of digital human modeling technology is still in nascent stage among many developing countries including India, as reported by Sanjog et al 2012. Digital human model tools require substantial monetary investment and training, which can be afforded mostly by large resourceful companies in developed countries. So, what important reason behind this less adoption of this technology is the initial investment?

At the beginning or purchasing the software, installing software, training of the manpower, then overall infrastructure setting it requires huge cost and this investment is many times not possible for low or very smaller industry or micro small and medium scale industry, and this is a bottleneck for the developing countries or underdeveloped countries, for this adopting this technology, because this companies or factory are unable to afford this technology due to the high cost.

The majority of small medium scale industries are still unaware about the digital human model tools as reported by Santos et al 2007. Not only the cost is involved, there are other factors like lack of awareness. So, many of the industry they does not know about importance of this software, and how the software can be used for better man machine interface, and for improving the overall manufacturing systems productivity and performance.

Lack of awareness is another factor, contributing to the negligible application of this technology, among fast developing countries or fast developing economics; like India, Pakistan, Bangladesh, Russia, Syria, Thailand, and other similar countries. The low rate of progression in adoption of advanced computing techniques might be important factor behind less use of this CAD and DHM in many developing countries. So, in this various authors highlighted what is are the reason behind less adoption of digital human modeling, based on virtual evaluation system in the developing countries.

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Now, I have tried to tabulate the use of digital human modeling software in various developing countries.

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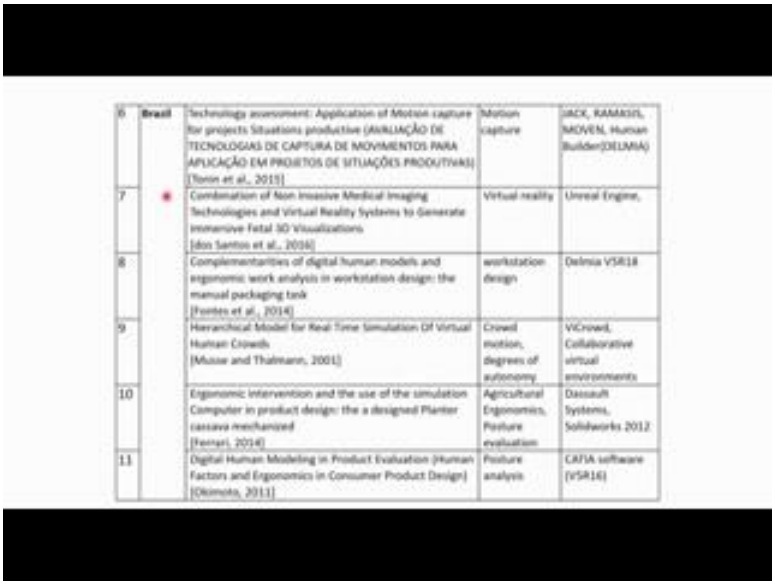

6	Brazil	Technology assessment: Application of Motion capture for projects Situations productive (AVALIAÇÃO DE TECNOLOGIAS DE CAPTURA DE MOVIMENTOS PARA APLICAÇÃO EM PROJETOS DE SITUAÇÕES PRODUTIVAS) [Tonin et al., 2015]	Motion capture	JACK, RAMSIS, MOVEN, Human Builder(DELMIA)
7		Combination of Non Invasive Medical Imaging Technologies and Virtual Reality Systems to Generate Immersive Fetal 3D Visualizations [dos Santos et al., 2016]	Virtual reality	Unreal Engine,
8		Complementarities of digital human models and ergonomic work analysis in workstation design: the manual packaging task [Fontes et al., 2014]	workstation design	Delmia V5R18
9		Hierarchical Model for Real Time Simulation Of Virtual Human Crowds [Musse and Thalmann, 2001]	Crowd motion, degrees of autonomy	ViCrowd, Collaborative virtual environments
10		Ergonomic intervention and the use of the simulation Computer in product design: the a designed Planter cassava mechanized [Ferrari, 2014]	Agricultural Ergonomics, Posture evaluation	Dassault Systems, Solidworks 2012
11		Digital Human Modeling in Product Evaluation (Human Factors and Ergonomics in Consumer Product Design) [Okimoto, 2011]	Posture analysis	CATIA software (V5R16)

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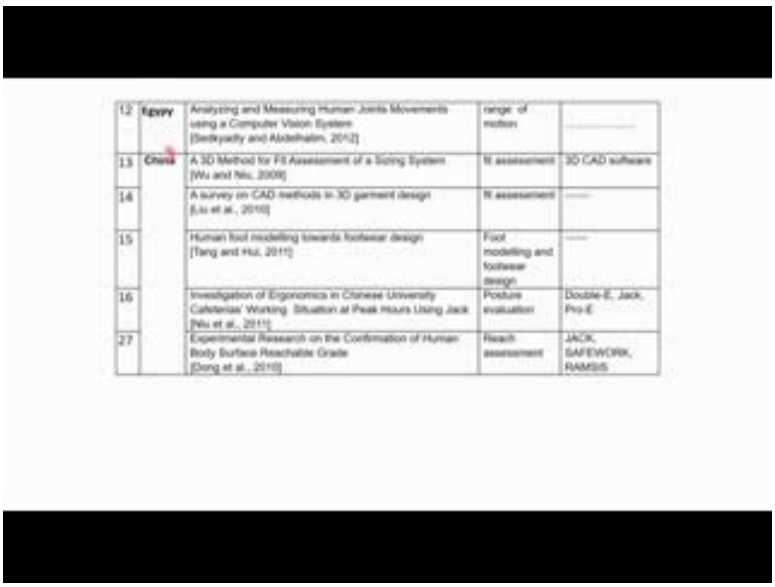

12	Egypt	Analyzing and Measuring Human Joints Movements using a Computer Vision System [Sedkyadly and Abdelhalim, 2012]	range of motion	.....
13	China	A 3D Method for Fit Assessment of a Sizing System [Wu and Niu, 2009]	fit assessment	3D CAD software
14		A survey on CAD methods in 3D garment design [Liu et al., 2010]	fit assessment	.....
15		Human foot modelling towards footwear design [Tang and Hui, 2011]	Foot modelling and footwear design	.....
16		Investigation of Ergonomics in Chinese University Cafeterias' Working Situation at Peak Hours Using Jack [Niu et al., 2011]	Posture evaluation	Double-E, Jack, Pro-E
17		Experimental Research on the Confirmation of Human Body Surface Reachable Grade [Dong et al., 2010]	Reach assessment	JACK, SAFEWORK, RAMSIS

Like Indonesia, Malaysia, Brazil, Egypt, china. Although china and India are moving towards, mean rapidly progressing towards developed country. Right now it is in the transition phase both the countries. It is moving from developing condition to the status of developing countries, from the developing countries to the status of developed countries. Now if you look at this table, they are in the number of publication or reported

literatures from these countries are very limited. Particularly from this if you look at Indonesia, only few literatures are available.

Similarly from Malaysia, the number of reported research which has been carried out in Malaysia; that is also hand countable. In Brazil the number is relatively more, but not that much in comparison to other developed countries, but in Egypt also it is very less. But in china and India good number of researches is being carried, but again if you look at into those countries, the publication is mainly coming from few research groups. it is not quietly a spread all over the country, or in most of the institution academic institution or research institution is still not adopting this technology. So, these are the references where from I made that table.

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Now, DHM related research and development activities in India. Now particularly we are going to highlight the application and research activities related to DHM, digital human modeling and simulation in Indian scenario. See if you look at application oriented reported research, then we will find that there are good number of reported research available from India. So, if I have tabulated first reported research area. So, in this column we have mentioned the filled up research, and this column describes the name of the authors for the reference.

So, digital human modeling is being applied for various workstation evaluation or product evaluation, or in different types of industries, so that has been tabulated here. So, for example, evaluation of workstation in aviation by Pinto and Taneja 2005, work coastal analysis by Mohan et al. then the interior design of a long haul truck cabin for improved human wellbeing, by Powar and et al in 2009. Then design the space spatial layout of equipment in playground by Karmakar in 2011.

In this way we will find other publication, related to ingress egress vehicle in anthropometric size measurement of Indian driving population, reconstructing a solid module from 2 d scanned images of biological organs, for finite elements simulation by kumara 2011. So, in this we will find the number of publication related to application of DHM are available from India.

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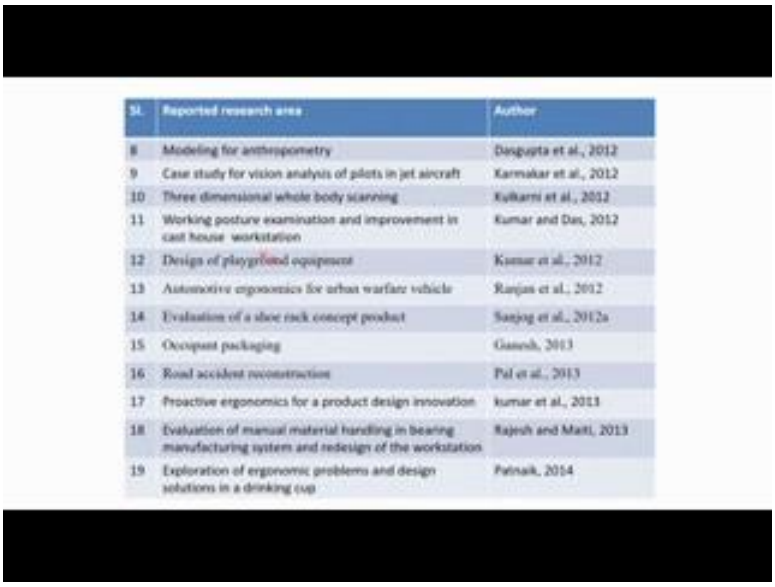

The list is being continued here, some modeling for anthropometry case study for vision analysis in aircraft cockpit, three dimensional whole body scanning, then automotive ergonomics for urban warfare, occupant packaging related, then road accident, proactive ergonomics for a product design innovation, evaluation of manual material handling, exploration of ergonomic problems and design solution in a drinking cup.

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Sl.	Reported research area	Author
20	Ergonomic intervention and evaluation of conference hall design	Kumar and Karmakar, 2014
21	Seat design of a bus	Chanda and Banerjee,2014
22	Ergonomic evaluation of manually operated pineapple peeling machine	Kumar and Chakrabarti, 2014
23	The postural assessment of a submersible pump assembly work	Sekaran et al., 2014
24	Ergonomic workplace evaluation for assessing Occupational risks in multistage pump assembly	Nishanth et al., 2014
25	Knapsack sprayer design	Bhuseand Vyavahare, 2014
26	Work-Related Disorders in Foundry Industry	Mali and Vyavahare, 2015
27	Plastic furniture manufacturing shop floor-granulator workstation	Sanjog et al., 2016a
28	Plastic furniture manufacturing shop floor-blending workstation	Sanjog et al., 2016b

So, in this you can find almost eighteen publications. All those publication are not in a good journal, many are in conference proceeding or not in the referred journal, but this is the overall scenario, and you can find all though India is big country, only twenty eight numbers of publication we can find as of 2016. So, this number is very less in terms of the, size of a number of institution, number of research organization in India. This number is very less. So, total twenty eight publications I could have found out.

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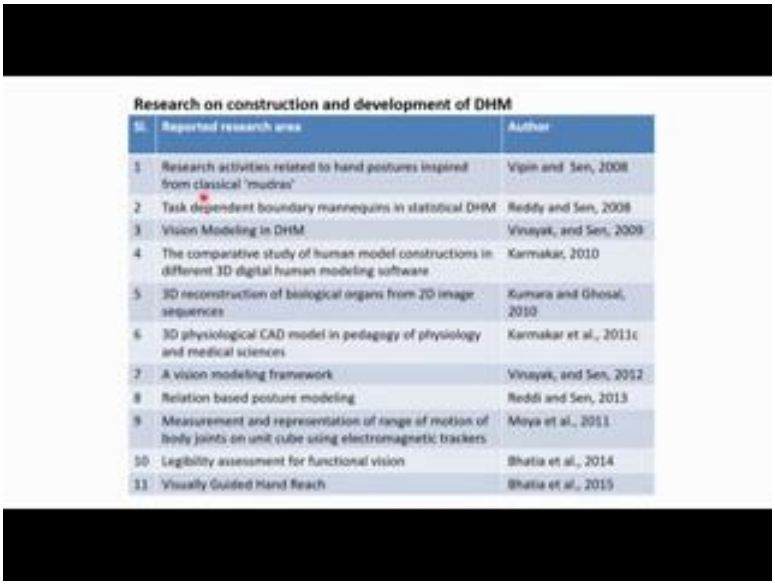

Research on construction and development of DHM

Sl.	Reported research area	Author
1	Research activities related to hand postures inspired from classical 'mudras'	Vipin and Sen, 2008
2	Task dependent boundary mannequins in statistical DHM	Reddy and Sen, 2008
3	Vision Modeling in DHM	Vinayak, and Sen, 2009
4	The comparative study of human model constructions in different 3D digital human modeling software	Karmakar, 2010
5	3D reconstruction of biological organs from 2D image sequences	Kumara and Ghosal, 2010
6	3D physiological CAD model in pedagogy of physiology and medical sciences	Karmakar et al., 2011c
7	A vision modeling framework	Vinayak, and Sen, 2012
8	Relation based posture modeling	Reddi and Sen, 2013
9	Measurement and representation of range of motion of body joints on unit cube using electromagnetic trackers	Moya et al., 2011
10	Legibility assessment for functional vision	Bhatia et al., 2014
11	Visually Guided Hand Reach	Bhatia et al., 2015

Similarly, while we are looking at research and construction of digital human modeling, means person or researcher who are involved in developing digital human model, or the whole detailing on software, or the digital human modeling structure, or its individual body parts. So, it is like hand modeling, foot modeling or head modeling for protective equipment. So, in this way if you see the research, related to digital human modeling, modal development and construction, the number of research reported from India are also very less; only eleven publication we can find out.

And most of the research are also by only one or, mean only form one or two research institute institution, or research organization. So, overall spread in this area that how digital human modeling can be made better, and how the software can be improved. So, in this direction the research is very limited in Indian scenario. So, to mention a few, research activities related to hand posture inspired from Classical Mudras by Vipin and Sen 2008.

In a vision modeling framework by Vinayak and Sen 2012, then visually guided hand reach by Bhatia et al 2015. Since only very few research papers we can find out.

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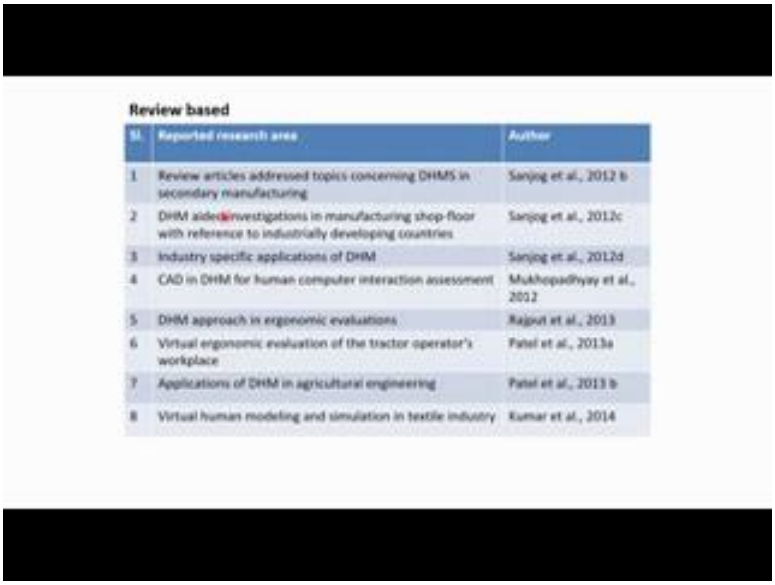

Then while you are moving to review based, mean various researches we have reported, regarding the application of digital human modal or digital human construction, mean ultimately review paper, the review paper written by also very few authors from India. So, total number of review paper as of now you can find out this is also twelve only. And

in this review papers, the authors mentioned various aspects of the human modeling; like CAD and digital human model.

For computer interactional assessment by Mukhopadhyay et al 2012, digital human modeling approach in ergonomic evaluation by Rajput et al 2013, application of DHM in agricultural engineering by Patel el al 2013, then virtual human modeling and simulation in textile industry by Kumars et al 2014.

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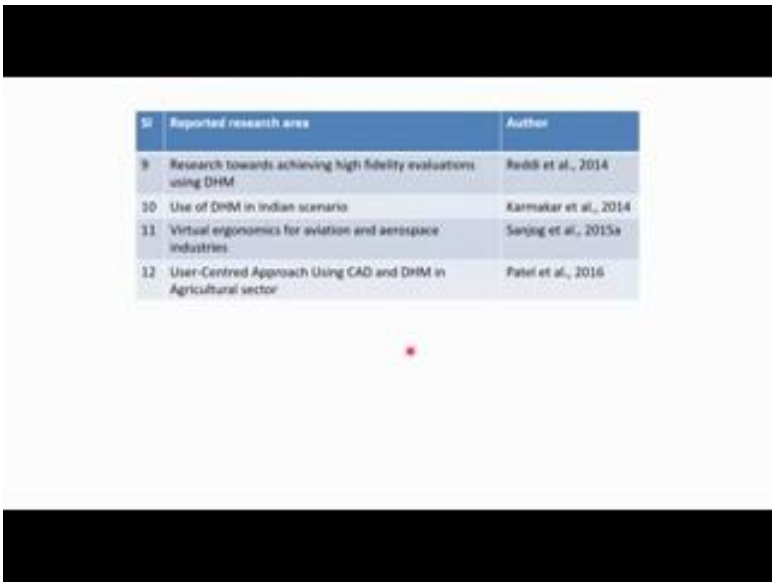

Research towards achieving high fidelity evolutions using DHM by Reddy et al 2014 use of DHM in Indian scenario by Karmaker et al 2014, virtual ergonomic for aviation and aerospace sector by Sanjog et al 2015, and recent one user centered approach using CAD and digital human modeling in agriculture sector.

So, in this only hand countable researches papers are available, which deals with the digital human modeling and its application, but mainly these are related to review. These are review based papers.

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Now, this is important to understand than what can be done, as in India and in other developing countries digital human modeling, is not that much popular, and its application is also very limited, then how it can be, what steps can be taken or wide spread adoption of this technology in developing countries. So, first awareness among researchers, scientist, engineers, designers, and entrepreneurs would achieve through organizing seminars, conference, workshop, etcetera as mentioned by Karmakar et al 2014. So, one way of achieving this goal of widespread adoption of the digital human modeling technology in developing countries may be through awareness.

There is need for collaboration among various industries academic institutions, and government or private organization all over the world, under one umbrella, to advanced virtual technology, mentioned by Patel et al 2016. Strategies for wide adoption of digital human model technology in developing countries like India should include integrating features of digital human model tools in general CAD software, which may result in reduction of cost to some extent.

Generally, digital human modeling software, right now commercially available in the market if we look at the software. So, it is capability of creating the workstation model or the overall virtual environment, which is needed to be evaluated, the capability of this softwares are very limited in that regards, mean it can be digital human model, it can create the whole workstation in virtual environment, but its capability as a CAD software

for generating complex model, and very big file, containing all the parts file and assembly file, for the whole environment that is very limited to the presently available software.

So, if we can integrate digital human modeling tools in general CAD software; like CATIA, unigraphic solid works, and then it will be easier, so only buying one software will serve the purpose. otherwise right now what is happening you have to buy digital human modeling software separately and CAD software separately, even making the CAD model of the product or workstation, in your in that CAD software, and importing the module to digital human modeling software for virtual ergonomic evaluation, but if these two can be integrated, then only one software will fulfill your purpose.

Research initiative for development of user friendly digital human modeling software, and making manikins more realistic, with incorporation of manikins representing Indian anthropometric dimension should be required as mentioned by Karmakar et al. If to make this technology popular in country like India, one important step that anthropometric database of Indian population to be incorporated in the digital human modeling. So, while people will use the, or researchers or designers or engineer, while they are using this digital human modeling software, they can directly create digital human model from that inbuilt anthropometric database. So, it will be very useful for them.

Subsidizing digital human modeling software initially to make it more economical and accessible as we mention earlier also the cost of this software and initially investment is high. So, if government or some other funding agency can subsidize this software, then it will be good for the researcher to adopt this technology, and it will be easier for them to use this type of software for their academic activities or for research purpose.

Digital human model still need to fill a significant gap with creation and emerging body of technical society, dedicated for advancing and popularizing that use of virtual technology, like CAD and digital human modeling, to solve real world problems. This is also mentioned by Karmakar et al 2014 and Patel et al 2016. So, these types of technical body or technical societies are to be established, which can take initiative for popularizing this virtual ergonomic evaluation technology throughout the world, including the developing countries.

These are the references from where we have prepared the slides. As we mentioned there are so many references. So, all these references are tabulated at the end. So, who are interested, the students who are participating in this particular course. I suggest all of them to go through all of these references, you can download these papers and go through to get better idea about what type of research is going on presently in India, related to either digital application of digital human modeling software, or related to its development.

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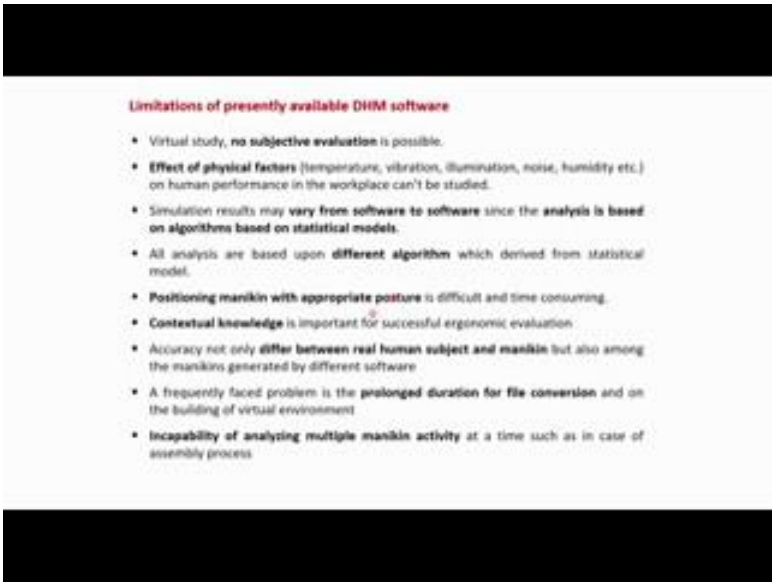

Now, as we mentioned in our first slide that in this particular module in module eight. We will discuss about limitations of presently available digital human modeling software. In the market there are so many digital human modeling softwares are available, commercially available and, but all those software have some limitation mainly may most of these softwares actually allow virtual evaluation or virtual study, no subjective evaluation is possible.

So, in this slide I have listed general few points, regarding the limitation of trade links commercially available softwares. So, first one is the, as the analysis is virtual in nature, and no subjective evaluation is possible, so that is a big limitation. Effect of physical factors like temperature, humidity, illumination noise, and how this effects human performance in work place that cannot be studied with this commercially available software presently available in the market, but research; obviously, research is going on

in this direction, in the near future probably it will be possible. And few softwares have already incorporating these features that.

So, we will discuss in next section that is related to future research scope of digital human modeling software. Simulation results may vary from software to software, since the analysis is based on algorithm, and that algorithm also depending on statistical model. So, that is also another limitation. So, how that software will perform; that is actually depending on which algorithm is incorporated in that software and how the reliable is the statistical model which that particular software or that modeling or simulation software is following.

All analysis is based upon different algorithm, which derived from statistical model, as I mentioned earlier. So, as this analysis is based on different algorithm. So, the output of the analysis, how effective or how reliable the analysis is, that is also dependent on the what type of algorithm, which software we are using, and in that software the background algorithm how much strong, or how much is reliable is there. So, depending on that the ultimate output is, output will be is achieved.

Positioning manikin with appropriate working posture, that is also time consuming and many a times difficult, so in this direction also advance research is going on. So, many softwares have already overcome the problem, and in many even few commercially available software right now, it is very easy to position digital human modeling, digital human modeling on the respective or interfacing the digital human model with the respective products or workstation model.

Another important aspect is contextual knowledge is important for successful ergonomic evaluation, and many a times it is found that there is lack of contextual knowledge, and due to that the overall evaluation is been suffering. Accuracy of analysis not only differs from real human subject and manikin, in digital manikin, but also from the manikin generated by different software. So, we can also find that there is very acute in terms of accuracy, while we are doing the analysis with the real human subject, and manikin there is some difference.

Not only this difference there is also difference while you are analyzing I mean through different software, to software to software, I mean one digital human modeling analysis of one digital human modeling software is differing from analysis done by another

software. A frequently faced problem is the prolonged duration for file conversion on the building of virtual environment. So, it takes enough time for file conversion, but as else the computing technology is advancing day by day. So, it will also be possible in your future, it will be possible in shorter time.

Incapability of analyzing multiple manikin activity at a time, such as in case of assembly process; so in assembly process while so many workers were working together at that time their interaction is very important and we need to evaluate that how people are interacting with each other, and during that time we need to open various types of ergonomic evaluation, but right now what is happening with all this digital human modeling software, mainly we can evaluate the various ergonomic aspects of work activities for a individual, or a single manikin, for multiple manikin the analysis is not possible simultaneously.

So, you have to complete the analysis for one particular manikin, after that you have to go for the next one. So, these are the general limitation as is observed with the presently available digital human modeling softwares.

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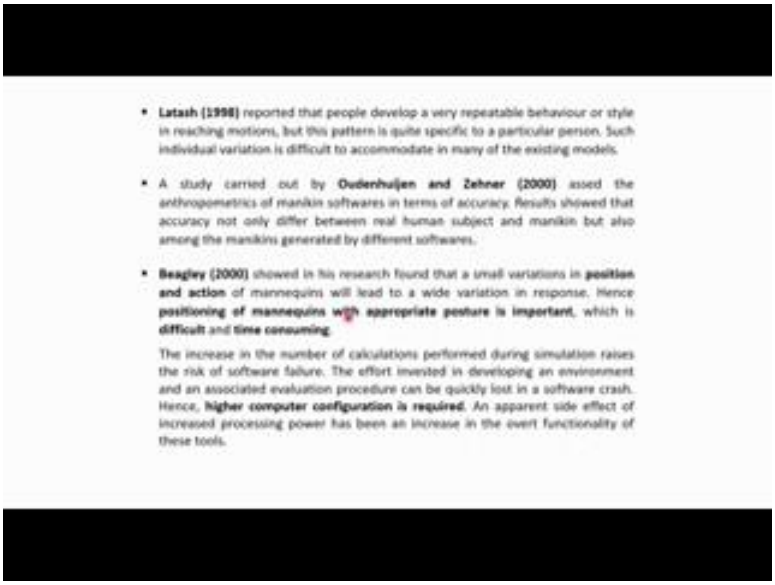

Now, in the subsequence slides we will discuss about the report or the statement by various researchers, regarding the limitation of digital human modeling software. So, Latash 1998 mentioned or reported that the people develop a very repeatable behavior or style in reaching motion, but this pattern is quite specific to a particular person. So,

during the reach analysis they found, that for a real person the pattern is quite specific for a particular each activity, such individual variation is difficult to accommodate in many of the existing digital human models.

A study carried out by Oudenhuijen and Zehner 2000, they assed anthropometrics of manikin software in terms of accuracy, results showed that accuracy not only differ between real human subject and manikin, but also among manikins generated by different softwares, as we mentioned in earlier slide. Beagley 2000 showed in his research that a small variation in position and action of manikins will lead to wide variation in response. Hence positioning of manikin with appropriate posture is very important, which is difficult and time consuming.

For many of the digital human modeling software giving appropriate posture to the digital manikin and positioning the digital manikin on the respective workstation or seat or chair or any other working place, or you are putting the digital human modeling for ergonomic evaluation. So, this positioning, appropriate positioning with appropriate working posture, to do that one it takes enough time. So, that is also a problem in many cases, but as the technology is being advanced.

So, in many of the software now it is possible to, because he has reported in 2000, but now in 2016, after this almost 16 years, now for the many of the commercial software it is possible to position digital human model very quickly. And also they are, is posture livery, from posture livery we can directly go for specific posture. The increasing number of calculation performed during simulation, raises the risk of software failure, and many time software hangs also.

The effort invested in developing an environment, and an associated evaluation procedure can be quickly lost in a software crash, because many times we have need to put a lot of effort for developing the environment, and at the time the software crashes, then you will lost the whole effort.

Hence, he stated higher computer configuration is required and apparent, so ham, this is very important for digital human modeling software or CAD based wall. So, high end computer with very good configuration with good graphics card, good processor that is required. And apparent side effect of increased processing power has been an increase in the over functionality of these tools.

He also mentioned as the advance increased processing power is required, at the same time while increased processing power is available with the advancement in technology, then the software developer they have incorporated n numbers of features, and during using the switches it is actually increase the overt functionality for use the tools, then many times it is difficult to find out the tools or menus for simply analysis.

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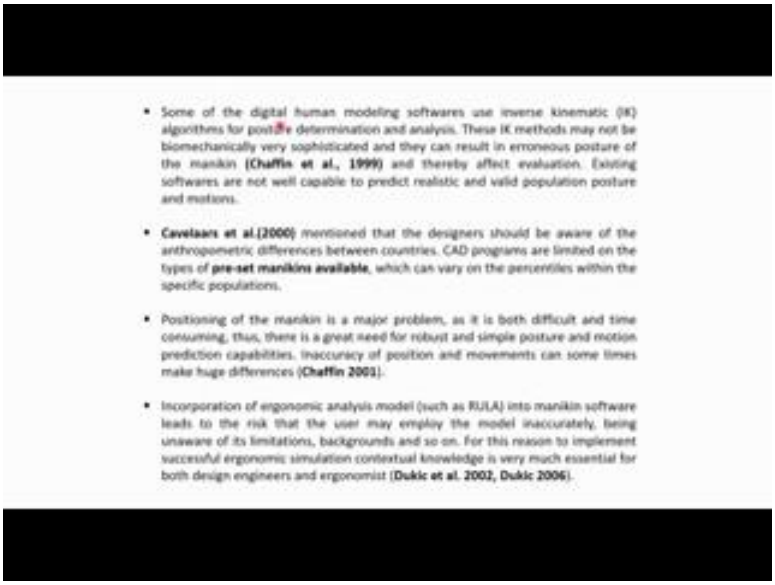

Some of the digital human modeling software use inverse kinematic algorithms for posture determination and analysis. These inverse kinematics methods may not be biomechanically very sophisticated, and they can result in erroneous postures of the manikin, as reported by Chaffin et al 1999, and thereby affect evaluation. Existing softwares are not well capable of predicting realistic and valid population postures and motion. Cavelaars et al 2000 mentioned that the designers should be aware of the anthropometric differences, between countries or population to population.

Cad programs are limited on the types of preset manikins available, which can vary on percentiles within the specific population. First problem related to many of the commercially available digital human model, is that the number of anthropometric database which is preset, is very limited. So, if for the software is being used for a particular nation or a particular population, if that anthropometric database is not incorporated in that software, then many times it is difficult by the user to create for creating the digital human model.

So, it is one important requirement is that the digital human modeling software or developer of the software should incorporate, maximum number of anthropometric database as much as possible, so that it can be, that software can be used all over the world, because if the particular anthropometric database. For example, if Indian anthropometric database is not incorporated in that digital human modeling software, then if that software is being purchased by researchers from India, then he or she will not be able to use that software. he can use, but as a, then it will be much more easier for him while the anthropometric database is already incorporating the software; otherwise he have to collect the anthropometric data, based on the data you have to calculate that percentile values, and based on that percentile values they can create percentile digital human model, or they can also use individual anthropometric data, and based on that data they can create a digital human modeling.

Positioning the manikin is a major problem as reported by other researchers also, as it both difficult and time consuming, and thus there is a great need for robust and simple posture and motion prediction capability. In inaccuracy of position and movements can sometimes make huge differences. So, this all reported by Chaffin in 2001, but right now in many of the software it is very use to position digital human modeling software to positioning digital human models, or interfacing the digital human modeling with the product model or with the workstation model.

Incorporation of ergonomic analysis model such as rula into manikin software, leads to the risk that the user may, employ the model inaccurately being unaware of its limitation, background and so on. For this reason, to implement successful ergonomic evaluation contextual knowledge is very important, or very much essential, for both design engineers and ergonomics. So, contextual knowledge of ergonomics is very essential for successful use of digital human modeling software for virtual ergonomic evaluation; otherwise the use of the digital human modeling software for various ergonomic evaluations will not be fruitful.

Chaffin 2005 identified that, there is lack of data sharing capabilities, thus requiring a designer to spend a great deal of time or extra time, for rendering a workspace or workplace with enough detail to perform an analysis.

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Many times it is found that data sharing capabilities of the software are also limited, and file conversion from one software to another software, there is also problem because in a particular software we can input only some specific file format. So, that is why only we can input those file which is comfortable for this, for particular software. So, data sharing capabilities of the softwares is needed be increased. Another limitation of present day digital human modeling software, is the incapability of analyzing multiple manikin activity at a time, we have already discussed this one.

Blanchonette 2010 found that the digital human modeling software could be suitable for task like ergonomic assessment of a cockpit, but not that much suitable for assessment of personal protective equipment of a pilot. So, while we are evaluating any particular general product or workstation then that is easy, but while we are going for evaluation of partly personal productive equipment, then specific face model or head model or specific hand model is required. Right now this commercial available software is not that much suitable for this purpose, for evaluating personal productive equipment, or personal equipment to fit a pilot, or any other workstation working condition, or workstation scenario.

Helander and Khalid 2012 stated that when using digital human model it is possible to make a task, it is possible to make a task look feasible, but when translated into manufacturing environment can only be accomplished with a high level of discomfort.

So, from digital human model analysis, it seems that probably this is feasible, but in real life while it is being implemented then various other problems are being encountered. So, physical discomfort is indicative of poor biomechanics, which can contribute to the development of m s d. So, more biomechanical feature, biomechanical analysis features to be incorporated in digital human modeling software.

So, Helander and Khalid also stated that the requirements like functionality attractiveness, ease of use affordability aesthetics and safety, that will evoke emotions, specially depend upon cognition are not considered in DHM. So, various aspects which is mainly dependent on cognition of the human, those aspects are not presently incorporated in digital human modeling software.

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The discomfort levels while completing the task have to be inferred by designers or engineers. If possible representative users such as those that will be directly interacting with the structure should be consulted, about perceived discomfort level of the structure. So, while designers or engineers are designing a particular product or workstation or any other facility, that time evaluation of digital human modeling through digital human modeling software is ok, but at the same time it will be good, if we can, at the same time take feedback from the representative users, because the subjective evaluation is not possible, various things like affordability aesthetics safety.

So, all this aspects which are related to cognitive, performance of the cognitive aspects of human being, those things can be evaluated with the representative user population. So, small representative with the help of small representative user population, we can evaluate the overall that concept model. Initial we can evaluate with the digital human modeling software to find out the anthropometric compatibility or anthropometric compatibility, what for various subjective evaluation purpose we can call for representative users. Johnson and Fletcher 2012 concluded that, because of limited anthropometric database there is a need to create large anthropometric and biomechanical database of various population across the globe, creating a manikin of a particular percentile of interest is a time consuming process.

So, they also highlighted these two aspect; that anthropometric database for different population that is also required, and at the same time many a times creating a particular percentile manikin of a particular percentile is time consuming. When modeling the posture of manikin, while interacting with the product. The postures adapted to the task from beginning to end should be modeled. Many a times what happen, we only identify some key posture and evaluate those key postures only, but for some activity. The working posture may be just as acceptable by postural analysis tools, while MSD risk lies in the transition postures not happen during the transition from one posture to another posture.

So, only identifying key postures for a particular activity and evaluation of those postures in virtual environment may not fulfill our purpose. So, for that purpose each and every step of the posture specific posture, as well as posture transition postures we need to evaluate. It was also found that subjective evaluation is not possible, only objective evaluation is possible; hence inputs or suggestion should taken from individuals outside, as also mentioned by Helander and Khalid, the representative users are required. So, Johnson and Fletcher they also mentioned the same thing individual. So, representative user population is very important, ideally this should be, this should include representative user. So, inputs and suggestion should be taken in terms of subjective aspects, those inputs is needed to be taken from the representative users.

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In their research paper Johnson and Fletcher reported that, there is a disconnection between what a designer perceives and what is possible within a manufacturing environment. Any concept or solution is limited by the perceptions of the people, who are working on the design; those designers are engineers.

So, the concept is limited or constant by their idea, their perception. For this reason representative user inputs is essential to identify the problems that may be missed in CAD based design using digital human modeling.

So, these are the various aspects, various limitation of presently available digital human modeling software, and reported by various researchers in the research paper.

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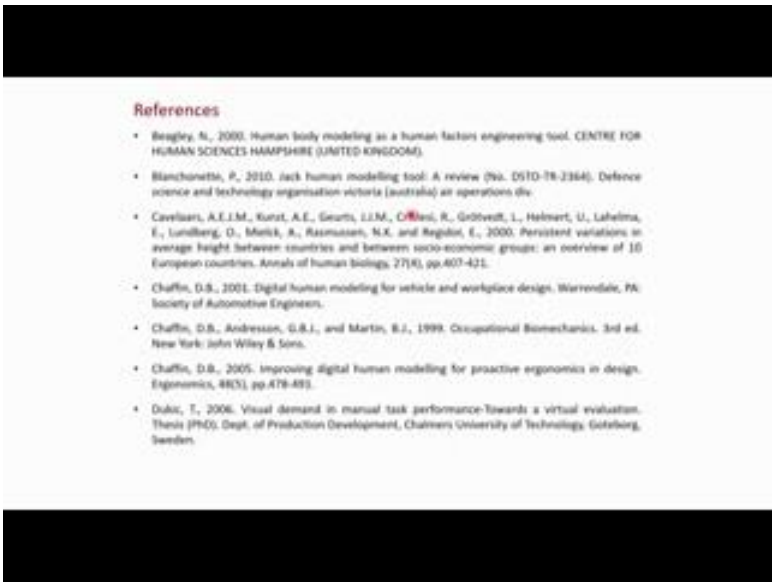

And these are the references.

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