A Seminar Report on:

“Digital Human Modeling”

Prepared by : Himanshu Choudhary

Roll. No. : U17CO101

Class : B.Tech –IV (Computer Engineering) 7th Semester

Year : 2020-21

Guided by : Dr. Krupa N. Jariwala

Department of Computer Engineering

Sardar Vallabhbhai National Institute of Technology,

Surat -395007 (Gujarat), India

Department of Computer Engineering
Sardar Vallabhbhai National Institute of Technology
Surat – 395007, Gujarat, India

Student Declaration

This is to certify that the work described in this seminar report has been actually carried out by

Sr.	Admission No.	Student Name
1.	U17CO101	Himanshu Choudhary

Neither the source code there in, nor the content of the seminar report have been copied or downloaded from any other source. I understand that my result grades would be revoked if later it is found to be so.

Signature of the Student:

Sr.	Student Name	Signature of the Student
1.	Himanshu Choudhary	

Surat -395007 (Gujarat), India

CERTIFICATE

This is to certify that the seminar report entitled **Digital Human Modeling** is prepared and presented by **Mr. Himanshu Choudhary** bearing Roll No. : **U17CO101**, 4^{th} Year of **B. Tech (Computer Engineering)** and his work is satisfactory.

GUIDE	**JURY**	**HOD**
(Dr. Krupa N. Jariwala)		**COED**

Contents

List of Acronyms

DHM Digital Human Modeling
IBL Intelligent Bionic Leg
PLM Product Lifecycle Management

Organization of Report

Chapter 1 includes a brief introduction of the Digital Human Modeling, Digital Human Modeling (DHM) Scope, category and some terminologies.

Chapter 2 includes the literature survey which gives an overview of Smart Clothing of Human Performance Evalution.

Chapter 3 gives in depth analysis of Motion Capture and Simulation including optimal arrangement of inertial sensors, human motion planning and methods.

Chapter 4 includes applications of Digital Human Modeling.

Chapter 5 presents the conclusions drawn from above chapters.

Abstract

Advancements in digital human modeling (DHM) and computer-aided design have been influential in revolutionizing the field of product design, healthcare, medicine, automotive, manufacturing industries. In the past two decades, DHM has been widely used in the fields of healthcare and medicine for designing prosthetic/orthotic based on patient's condition. With the ease in developing digital models and the reduction of the cost involved in the process, it has also found its application in the fields of costume design, furniture design, and automobile design. DHM has been most prominently used where there is a high need of customization. In addition, generic, partial, and full body models have been created from large databases using different computational techniques, which can be used in deciding optimal sizing and grading parameters for different products. This can help in mass production and mass customization of such products.

Keywords: Digital Human Modeling - Virtual Human - Body Template - Computer Manikin

Chapter 1

Introduction

Digital Human Models (DHM) have matured from simple drawing templates and topics of abstract research to complex and integrated design and analy-sis tools for multiple industrial applications. They are frequently used by engineers, designers and others to allow an early consideration and inclusion of characteristic human factors in the design of new products, processes and systems. DHM support the ergonomic evaluation of new product designs during early design stages by modeling anthropometry, posture, motion or predicted discomfort. It is also an effective and efficient way to accelerate the total design process. Today, most DHMs model human anthropometry and biomechanics to facilitate, e.g., sight, reach, and comfort analyses. Others model human simulate performance and allow planning and optimization of workplaces and production processes. By integrating different types of DHM systems in a holistic approach, more comprehensive simulations and analyses during early design phases will become possible. Such a holistic approach will increase speed of design for innovative products and production systems significantly.[1].

1.1 What is Digital Human Modeling ?

Digtal Human Modeling is the process of developing digital human models using anthropometric and biomechanical database, for ergonomic evaluation of product and workstation in virtual environment, using 2D or 3D CAD softwares. The digital human modeling combines information technology with bioscience, applied to analog study from DNA molecule and protein to cell and tissue, as well as organ. It has been widely implemented in various fields such as aviation, national defense, film and television, sports and medical treatment.

1.2 DHM Scope, Category and Terminology

- Ergonomics Modeling: Application of scientific information conserning humans to the design of objects, systems and environment for human use. Modeling - Posture, Movement, Physical capabilities, Cognitive capabilities
- Anthropometrics Modeling: Concerned with the physical sizes and shapes of humans, including height, size, weight, and body segment proportion. Variation with gender,

age, and ethnicity. Applications ranging from clothing, furniture, automobiles, buses and subway cars to space shuttles and space stations.

- Biomechanical Modeling Techniques: i) Rigid multi-body dynamics- Entire body divided into a number of segments. Each segment treated as a rigid body, linking to another with joints. ii) Finite Element Method - Using small elements to describe the bones, soft tissues, and organs. Incorporating biological material models, describing stress and strain.

[2]:

Chapter 2

Smart Clothing for Human Performance Evalution

Evaluating human performance and identifying critical constraints in the humanmachine-environment system is a challenge: the high number of variables and their mutual relationships and influence on the multiple degrees of freedom make it a complex task. Despite this complexity an ecologic approach is needed to analyse the system in its natural functioning. Smart clothing provides a solution to monitor in real time mechanical, environmental, and physiological parameters in this ecological and nonintrusive approach. These parameters can be used to detect gesture or specific patterns in movements, to design more efficient specific training programs for performance optimization, and screen for a potential cause of injury. Designing a fitting and comfortable sensing garment should consider at the beginning the analysis of human dimensions and requested actions to be carried out.

2.1 Introduction of Smart Clothing

The smart cloth represents a "second skin" that has a close, "intimate" relation with the human body. The relation is physiological, psycological, biomechanical and ergonomical. Effectiveness of functional wear is based on the integration of all these considerations into the design of a smart clothing system. The design process begins through the analysis of the anticipated user and the identification of the end-user's needs. Design and technological issues are the two main macro areas involved in the process together with the esthetical one. Once these criteria have been established, the initial esthetic design is created within the framework of the user's needs. Design decisions are evaluated and re-evaluated based on physiological, ergonomical and biomechanical monitoring of the wearer's performance. As a consequence, alternative solutions are generated for each decision. Alternatives are then evaluated on a weighted scale, to arrive at the best solution or combination of solutions for each decision.[3]
For example let us take solider's smart t-shirt and understand its working. The smart t-shirt is capable of monitoring the heart rate (ECG) and the 3D body accelerations of the trunk in real time. Bluetooth communication allows the real-time communication with a custommade APP suited for the purpose. The information can be either stored or immediately transferred to a nearby computer for the successive analysis. Smart tshirt capabilities can potentially monitor the soldier's performance in terms of training, injuries, and psychological status monitoring.

Physiological, ergonomical and biomechanical evaluation of soldier's performance were considered for the functional need of the end-user.

2.2 Garment co-design workflow

Workflow includes:

- Identification of user needs : At the beginning of the workflow, identify the user's need through a questionnaire collected on a population. The needs and the wishes were transformed in product requirements. After that, product requirements were translated in design requirements for the functional design cloth.

- Fabric selections and traditional pattern : A first draft was designed taking in cosideration the body mapping of sweating in male athletics. Two different textiles were combined, trying to respect the sweat rate of the subject. The first was used as principle structure because of the reduced elongation and sweating rate. Despite the high number of grams per meter it is 2 times tinner than any other of similar weight. This make it also breathable. Second textile was used in higher sweating rate areas and where more freedom and elongation was necessary. Regarding the performance both materials have honeycomb construction allowing air circulating between the fibers. A bonding technique with adhesive tape was used to join the fabrics together creating the 3D shell.

2.3 Functional Evaluation

The evaluation of functioning in the two prototypes started with biomechanical, ergonomical and physiological requirements of the end-user during different tasks. The physiological evaluation was specifically related to the position of the garment and the adherence of the textile to the body, while the biomechanics and ergonomics dealed with the thermal discomfort and agility.[4]

Chapter 3

Motion Capture and Simulation

Digital human models can be used to estimate workloads on the body when actual work motions are input correctly and interactive musculoskeletal simulations are carried out.

3.1 Optimal Arrangement of Inertial Sensors on a Motion Measurement Suit

Labor shortages caused by an aging population have made it more common to manage workloads to extend healthy work life. To prevent work-related injuries and to make work more sustainable, it is important to analyze the actual motion of workers. We are currently developing a system for evaluating workloads and the effect of a wearable assistive device using a digital human model (DHM). In this system, work motion in a real environment is measured by inertial sensors. Each sensor comprises a three-axis accelerometer and a three-axis gyroscope which are less affected by surrounding environment unlike optimal motion capture systems. When measuring motion in a real workplace, it is desirable to avoid disturbing the work process and to minimize the setup time. Thus, motion measurement suits equipped with inertial sensors have been developed to capture the working motion regardless of the work environment. When inertial sensors are used to obtain motion data for a DHM, measured angles need to be converted into bone inclination angles to give motion information. This conversion involves relationship between the inclination of bones and sensors. However, fixing sensors on the suit decreases its adaptability owing to the individual differences in physique, which means that the relative positions between the sensors and the body change from the expected position. In the case of multi-linked parts, such as the trunk, these changes in position affect the result of a measurement shortages caused by an aging population have made it more common to manage workloads to extend healthy work life. To prevent work-related injuries and to make work more sustainable, it is important to analyze the actual motion of workers. We are currently developing a system for evaluating workloads and the effect of a wearable assistive device using a digital human model (DHM). In this system, work motion in a real environment is measured by inertial sensors. Each sensor comprises a three-axis accelerometer and a three-axis gyroscope which are less affected by surrounding environment unlike optimal motion capture systems. When measuring motion in a real workplace, it is desirable to avoid disturbing the work process and to minimize the setup time. Thus, motion measurement suits equipped with inertial sensors have been developed to capture the working motion regardless of the work environment. When inertial sensors are used to obtain motion data for a DHM, measured angles need to be converted into bone inclination angles to give motion information. This conversion involves relationship between the inclination of bones and sensors. However, fixing sensors on the suit decreases its adaptability owing to the individual differences in physique, which means that the relative positions between the sensors and the body change from the expected position. In the case of multi-linked parts, such as the trunk, these changes in position affect the result of a measurement

3.2 A framework for motion planning of digital humans using discrete mechanics and optimal control

Although the degree of automation is increasing in manufacturing industries, many assembly operations are performed manually. To avoid injuries and to reach sustainable production of high quality, comfortable environments for the operators are vital. Poor station layouts, poor product designs or badly chosen assembly sequences are common sources leading to unfavorable poses and motions. To keep costs low, preventive actions should be taken early in a project, raising the need for feasibility and ergonomics studies in virtual environments long before physical prototypes are available.

Today, in the automotive industries, such studies are conducted to some extent. The full potential, however, is far from reached due to limited software support in terms of capability for realistic pose prediction, motion generation and collision avoidance. As a consequence, ergonomics studies are time consuming and are mostly done for static poses, not for full assembly motions. Furthermore, these ergonomic studies, even though performed by a small group of highly specialized simulation engineers, show low reproducibility within the group.

To describe operations and facilitate motion generation, it is common to equip the manikin with coordinate frames attached to end-effectors like hands and feet. The inverse kinematic problem is to find joint values such that the position and orientation of hands and feet matches certain target frames. For the quasi-static inverse kinematics this leads to an underdetermined system of equations since the number of joints exceeds the end-effectors' constraints. Due to this redundancy there exist a set of solutions, allowing us to consider ergonomics aspects, collision avoidance, and maximizing comfort when choosing one solution.
The dynamic motion planning problem is stated as an optimal control problem, which we discretize using discrete mechanics. This results in a nonlinear constrained optimization problem, which can be solved using standard nonlinear programming solvers. Furthermore, this general problem formulation makes it straight forward to include very general constraints and objectives.[5]

3.3 Human motion planning

The manikin model is a tree of rigid bodies connected by joints. Each body has a fixed reference frame, and we describe its position relative to its parent body by a rigid transformation T(q), where q is the coordinate of the joint. To position the manikin in space, with respect to some global coordinate system, it has an exterior joint positioning the manikin relative to a fixed inertial frame. For a given configuration of each joint, collected in the joint vector q = [q1,...,qn]T, one can calculate all the relative transformations T,traverse the tree beginning at the root and propagate the transformations to get the global position of each body. We say that the manikin is placed in a pose, and the mapping from a joint vector into a pose is called forward kinematics. Furthermore, a continuous mapping q(t) where tER, called a motion, or a trajectory of the system.[6]

3.4 Anticipatory models of human movements and dynamics

Future robots will need more anticipation capabilities, to properly react to human actions and provide effeicent collaboration. To achieve this goal, we need new technologies that not only estimate the motion of the humans, but that fully descibe the whole-body dynamics of the interaction and that can also predict its outcome.

Here the roadmap of AnDy, which leverages existing technologies to endow robots with the ability to control physical collaboration through intentional interaction. To achieve this goal, AnDy relies on three technological and scientific breakthroughs. First, AnDy will innovate the way of measuring human whole-body motions by developing the wearable AnDySuit, which tracks motions and records forces. Second, AnDy will develop the AnDyModel, which combines ergonomic models with cognitive predictive models of human dynamic behavior in collaborative tasks, learned from data acquired with the AnDySuit. Third, AnDy will propose AnDyControl, an innovative technology for assisting humans through predictive physical control based on AnDyModel.

By measuring and modeling human whole-body dynamics, AnDy will provide robots with a new level of awareness about human intentions and ergonomy. By incorporating this awareness on-line in the robot's controllers, AnDy paves the way for novel applications of physical human-robot collaboration in manufacturing, health-care, and assisted living.

3.5 Methods

The ability to collaborate with humans requires that the robots have the ability to provide physical assistance to people that needs help in performing a certain task. The fundamental assumption is that physical collaboration requires the robot to understand what the partner is doing and

predict what the partner is going to do. This requires a model of the partner, and since we are not only interested in the motion but also in the effort, we need a comprehensive model that contains kinematics and dynamics information of the human.
Developing models requires observations, and to make appropriate observations to study a phenonmenon often we need to create new tools. This paradigm is recurrent in our history since centuries: for example, the Newtonian telescope was used to observe celestial orbits, which led to the universal gravitation law. In a similar way, to develop anticipatory controllers that enable robots to collaborate with human partners(AnDyControl) we need predictive models of the human motion and dynamics(AnDyModel); to create these models, we need to collect observations of collaborating partners(AnDyDataset), with a novel tool(AnDySuit) that allows us to fully measure the kinematics and dynamics of the humans.

- The AnDySuit: This is going to be a breakthrough technology that allows us to fill the blind spot of measuring human-robot physical interaction. The AnDySuit is a wearable device that monitors in real-time the kinematics and dynamics of the human: that is, it provides the whole-body posture and whole-body dynamics. By processing the kinematics and dynamics measures, it allows retrieving important variables for collaboration, such as the contact stiffness, the gaze direction and for ergonomics, such as the body posture.

- The AnDyDataset: The AnDySuit will enable us to record the motion and dynamics of a human performing different tasks, of two humans collaborating, and of a human collaborating with the robot. The kind of recordings we will do are unique in their kind, as we will mix wearable inertial measures, force/torque measures, motion capture, etc. This will allow us to record kinematics descriptors of the actions as well as dynamics descriptors. Data collection will take place both in research labs and in real manufacturing scenarios. Experimental protocols with ethics committee approval will be obtained by the parteners leading the data collection.

- The AnDyModel: The AnDyDataset will enable the development of models of human motion and dynamics and human collaboration. Accurate dynamics models will rely on the musculo-skeletal models of AnyBody, but model reduction and strong optimization will be obtain real-time signals. We aim at three different types of models: ergonomics models, that are used to retrieve relevant metrics for assessing the ergonomics impact of the motions, based on the metrics of the standard evaluation tools (e.g., EAWS, OCRA) (GLAESER et al., 2014); classification models, that are used to recognize the current activity of the human; and predictive models, that are used to predict the future evolution of the dynamics and motion of the human (e.g., the goal position of a reaching action, as well as the joint torques that are necessary to accomplish the movement). For the latter, we will explore different machine learning tools, ranging from probabilistic movement primitives to deep neural networks.

- The AnDyControl: the final objective is to develop online control strategies for physical human-robot collaboration. Thanks to the AnDySuit, we can measure the human motion and its dynamics in real-time. These observations can be used to make predictions using the prior information provided by the AnDyModel, for example predicting the goal of a human movement, which forces or trajectories to expect. The AnDyControl here has the goal to adapt the robot control strategy in real-time, taking into account such predictions, with the purpose to optimize the collaboration, particularly the ergonomics criteria of the human movement.

Chapter 4

Applications of Digital Human Modeling

- Anthropometric Analyses of Crew Interfaces and Compoent Accessiblity for the International Space Station : Engineers often use different types of modeling and simulation to test crew station prototypes. A variety of tools exist to perform these types of analyses each with their own advantanges. However, using these tools can be time-consuming and quite difficult, especially when engineers try to utilize the output of one tool as the input to another. Digital Human Modeling helps engineers to visualize and optimize their choices of controls and displays, and the position of different elements in a workstation.[7]

- Human Model Evaluations of Air Force System Designs : Body size accommodation in cockpits is still a significant problem despite all the years of experience and the many aircraft designs that have been developed. Adequate reach to controls, body clearances and vision are all functions of pilot body size and position in the cockpit. One of the roots of this problem is the way cockpit accommodation is specified and tested. For many years the percentile pilot has been used. There are errors inherent in the percentile man approach, and presents a multivariate alternative for describing the body size variability existing in a given flying population. A number of body size representative cases are calculated which, when used properly in specifying, designing, and testing new aircraft, should ensure the desired level of accommodation. The approach can be adapted to provide anthropometric descriptions of body size variability for a great many designs or for computer models of the human body by altering the measurements of interest and/or selecting different data sets describing the anthropometry of a user population. Anthropometry, Crew station design, Ergonomics, Size

- Evaluation Using Human Modeling Systems and Virtual Environments : The multi-embodiment solution is to actively embody the user in the design and evaluation process in virtual reality, while simultaneously superimposing additional simulated virtual bodies on the user's own body. This superimposed body acts as the target and enables simultaneous anthropometrical ergonomics evaluation for both the user's self and the target. Both virtual bodies of self and target are generated using digital human modeling from statistical data, and the animation of self-body is motion-captured while the target body is moved using a weighted inverse kinematics approach with end effectors on the hands and feet

- Application in Automobile industry :
  - Automobile Crashworthiness Modeling.
  - Occupant-Airbag Interaction Modeling
  - Testing Vehicle with Digital Human Models.
- DHM application in Sports : DHM was applied by Holmberg et al. for understanding the effect of the impairment on sport's performance. In their study musculoskeletal simulation for skiing sport was carried out on digital manikin with lower leg prosthesis. The influence of technique, fitness, and training was taken as negligible. Two full-body simulation models with identical anthropometric data were created having similar kinematics and external kinetics. In order to assess the impact of prosthesis on muscular work, one model was composed of full muscle setup and the other without muscle setup in right lower leg and foot. Biomechanical simulation of cross-country skiing was performed on both manikins. The output was used for computing metabolic muscle work and skiing efficiency. The results indicated that without muscles in leg and foot, skiing demanded more muscular efforts in total.
- Need of DHM application for improving the work environment of the specially-abled and elderly : Following the literature review, it is evident that a large number of research and developmental activities have been carried out by applying DHM in product and workplace design for military personnel, automobile drivers, healthcare professionals and for general civilian populations. Researches on DHM applications in the design and development of products for specific population subgroups like elderly and specially-abled persons have received less attention. Thus, there is a scope for need-based design of products and support systems for such specific sub-populations by taking the advantages of DHM technologies. A user-centric work environment or ergonomic products is an utmost necessity for the specially-abled or elderly as they encounter various barriers like inadequate policies and standards, negative attitude, lack of provision of services and the problem with service delivery, etc. Specially-abled employees who work in uncomfortable workplaces have also complained of mobility trouble, problems associated with heart and blood circulation, depression, etc. They also face difficulties while traveling and using public transport, which prevents their participation in social and work life. Apart from that, specially-abled persons also encounter other disparities like lower average pay, job insecurity, lack of training facilities, participation in decision-making, etc. . Hence, convenient housing and adequate support services should be provided to the

specially-abled or elderly people. Moreover, planners, designers, and architects should adopt universal and inclusive designs approach to remove obstacles in accommodation, transportation and communication to empower the specially-abled to participate independently and comfortably in education, employment and social life. In the scenario described above, virtual prototyping with DHM could enable the designer to evaluate the product and modify it by simulating the interaction of digital manikin with the CAD model of the product [34]. Digital manikin-based virtual testing of the product-user interface also reduces discomforts/troubles to the elderly and specially-abled persons by eliminating their actual participation in real experiments of physical compatibility evaluation.

- Application of DHM software for improving the work environment : Digital human modeling software has gained attention for proactive design and ergonomic evaluation of products and workplaces in diverse fields that include manufacturing industry, healthcare sectors, transportation, agriculture, defense research and development, aerospace-aviation sectors and so on. In industrial workplace, DHM has been applied for improving the designs of work cells in car manufacturing plants, designing of small fishing vessels to reduce work-related musculoskeletal disorders of fisherman, redesigning of work accessories for minimizing awkward postures in Indian shop floor workstation, workplace evaluation of coir industry, etc..

  The ergonomic analysis of refrigerated cabinets, shoe rack, adjustable walking cane, modified cycle rickshaw, improved load carrier for coolie improved design of wearable load assisting device etc. are few examples where DHM has been applied effectively. In the healthcare sector, DHM has been successfully utilized for improving laparoscopic surgery, evaluation of bathing system design for patients, patient lifting devices for healthcare personnel, etc.

  DHM also finds its application in the field of transportation, aviation, and aerospace viz. vision analysis of pilots in jet aircraft, evaluation of cockpit design, vehicle interior design, evaluation of seat belt, driver posture and comfort in vehicles. Inclusion of DHM in the design process of the agricultural tools and machinery is also gaining popularity.

- Application in Healtcare industry : Healthcare sector is also taking benefit of DHM technology for designing prosthesis, exoskeleton and assistive aids. Morotti et al., Colombo et al. and Colombo et al. created two digital human models for transtibial amputee and transfemoral amputee. Its gait was simulated for analyzing causes of gait deviations related to prosthesis set up and socket modeling. A system for designing sockets for lower limb prosthesis was also developed. This system designs sockets based on the patient's weight, lifestyle, tonicity level and geometry of residuum. A virtual prototype of Intelligent Bionic Leg (IBL), an advanced trans-femoral prosthesis, was developed and virtually evaluated by Xie et al. For designing exoskeletons, musculoskeletal analysis of upper limb exoskeleton in a simulated environment was performed. In this way, the designs of the exoskeleton can biomechanically be evaluated before making an actual prototype. To analyze the effect of the strap that connects the exoskeleton with the human body, a combined human exoskeleton model was developed and evaluated in a simulated environment. Virtual prototyping of rehabilitation exoskeleton by merging computational musculoskeletal analysis with simulation was also proposed. In the proposed framework an exoskeleton–limb musculoskeletal model is developed first and then its performance is assessed using biomechanical, morphological and controller parameters. These parameters are optimized for developing the virtual design. The virtual experiment is then carried out to generate a modification in the design if required. The application of such a framework was illustrated by developing the index finger exoskeleton prototype.

In the area of assistive aids, a modified DHM tool was applied for ergonomic evaluation of a bathing system design from caretakers' (elderly) and caregivers' point of view. Most suitable bathing posture was also defined. Anthropometrics, joint range of motion, description, and appearance were customized for developing manikins of the elderly. RULA and joint comfort values were used to evaluate bathing system design. A walker with sit-stand assistance for the elderly was developed and virtually evaluated on the human model before experimenting on real users. A sit to stand and mobility assistance device for the elderly was also developed and virtually evaluated by Khan et al. Out of numerous case examples, two prominent usages of DHM in the design of prosthesis for the person with amputated leg and assistive aids for the elderly and specially-abled have been depicted in Fig. 1 for the easy understanding of the readers.[8]

Application of virtual human for assisted healthcare is also evolving. The virtual human with characteristics like speech recognition, natural vision, and language allows a human user to interact with their computer in a more natural way. The virtual human monitor the type of user such as old age person or disable, record data from sensors and communicate the data to healthcare professionals. Currently, virtual patient technology has been applied for mental health diagnosis and clinical training. Kakijaki et al. applied digital human modeling to physiotherapy education for 3D visualization and analysis of gait motion of the normal and hemiplegic patient

- Head-Neck Injury Modeling
- Seating Comfort Modeling - Bony Struction model, 3-D scan data and outer shape model, Simulation of pressure distribution between the seat cushion and buttock.
- Human Physiological Function Modeling - Physiological function modeling : Cardiovascular function(blood circulation), Lung function(Inhalation/exhalation), Other Physiological function modeling.

– Sitting Arterial/Venous Circulatory Simulation

Chapter 5

Conclusion

From above applications of DHM it is clear that it is going to play an important role in many industries. For today, it is the beginning of DHM and when this will advance it definitely going to change the world around us. Aim is to develop anatomically and bio-mechanically sound human models. Due to the complexity of modelling human body and data availability the improvement is slow in DHM but as computational power and resources are increasing very rapidly, the day is not far when one can experience fully grown Digital Human Model.

Starting from Smart Clothing it is clear that how the road-map will go on collecting necessary data and utilizing it in improving the models. DHM covers many complex topics starting from sketching, human motion, pose detection to automation. Ergonomic evaluation of visual demands becomes crucial for the operators/users when rapid decision making is needed under extreme time constraint like navigation task of jet aircraft. Research reported here comprises ergonomic evaluation of pilot's vision in a jet aircraft in virtual environment to demonstrate how vision analysis tools of digital human modeling software can be used effectively for such study.

DHM in Scientific Research Fields Automobile Industry As a driving force for DHM development, the automotive industry has traditionally used human models in the manufacturing sector (production ergonomics, e.g. assembly) and the engineering sector (product ergonomics, e.g. safety, packaging). These models are optimised for a seated posture, interface to a vehicle seat through standardised methods and provide linkages to vehicle controls.
A Formula 1 race car and a marine vessel were developed by the integration of Product Lifecycle Management (PLM) and DHM software packages. Dassault Systemes' CATIA V5 PLM solution package was used for CAD/CAE design/analysis and UGS Tecnomatix JACK software was utilized for visual/mathematical ergonomics and human analysis. Literature review for future work, was discussed to investigate the potentials of DHM in PLM for simulation of a blast motion in Navy vessels. The results and observations indicated that integration of DHM and PLM packages have potentials to improve the product development efforts and offer an enhanced approach for simulation of complex systems where there is human-machine integra-

tion.

The application of numerical simulation incorporating digital human models offers exciting opportunities in automotive development. Applying human models in comfort, ergonomics and safety allows to overcome limitations imposed by the use of real humans or their mechanical surrogates and thus enables further optimization of automotive designs.

References

[1] V. Duffy, *Digital Human Modeling*, 01 2009, vol. 4561.

[2] E. Billing, L. Hanson, M. Lamb, and D. Högberg, "Digital human modelling in action," 11 2019.

[3] W. Zhu, X. Fan, and Y. Zhang, "Applications and research trends of digital human models in the manufacturing industry," *Virtual Reality Intelligent Hardware*, vol. 1, no. 6, pp. 558 – 579, 2019. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S2096579619300828

[4] P. Shah and Y. Luximon, "Chapter 44 - use of digital human modeling in product design," in *DHM and Posturography*, S. Scataglini and G. Paul, Eds. Academic Press, 2019, pp. 591 – 598. [Online]. Available: http://www.sciencedirect.com/science/article/pii/B9780128167137000441

[5] K. Jung, O. Kwon, and H. You, "Development of a digital human model generation method for ergonomic design in virtual environment," *International Journal of Industrial Ergonomics*, vol. 39, no. 5, pp. 744 – 748, 2009. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S0169814109000584

[6] H. O. Demirel and V. G. Duffy, "Digital human modeling for product lifecycle management," in *Digital Human Modeling*, V. G. Duffy, Ed. Berlin, Heidelberg: Springer Berlin Heidelberg, 2007, pp. 372–381.

[7] ——, "Applications of digital human modeling in industry," in *Digital Human Modeling*, V. G. Duffy, Ed. Berlin, Heidelberg: Springer Berlin Heidelberg, 2007, pp. 824–832.

[8] K. Fan, A. Murai, N. Miyata, Y. Sugiura, and M. Tada, "Multi-embodiment of digital humans in virtual reality for assisting human-centered ergonomics design," *Augmented Human Research*, vol. 2, 12 2017.

Acknowledgement

I humbly take this opportunity to express my sincere gratitude and special thanks to Prof. Dr. Krupa N. Jariwala who took time out to hear, guide and show the right path. I would also like to express my gratitude to the faculty of Computer Engineering Department, Sardar Vallabhbhai National Institute of Technology, Surat for helping me directly or indirectly. Last but not the least, I would also like to thank Prof. Dr. Udai Pratap Rao, for heading the management involved in organizing seminars in a really structured manner. I will strive to use the gained knowledge in the best possible way.