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An Aid to Dynamic Task Simulations

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Abstract

The rapid introduction of sophisticated computers, services, telecommunications systems, and manufacturing systems has caused a major shift in the way people use and work with technology. In today's global marketplace, product design engineers often face the challenging task of ensuring that their products can be manufactured, installed, used and serviced by people around the globe. Now-a-days one can connect 3D product designs to their intended target audience using new, integrated, easy-to-use human modeling solutions that save time and cost by reducing expensive physical prototypes, and make the process of performing ergonomics and human factors analyses easily accessible to all.

Introduction

Digital human modeling (DHM) is rapidly emerging as an enabling technology and a unique line of research, with the promise to profoundly change how products or systems are designed, how ergonomics analyses are performed, how disorders or impairments are assessed, and how therapies or surgeries are conducted. Characterizing and understanding the human shape variation is also essential for many applications, ranging from product design, clothing to health monitoring.

Digital Human Modeling is treated both as a technology and as a fundamental research area, in the context of computer-aided ergonomics or human-centric design. As a technology, digital human modeling is a means to create, manipulate, and control human representations and human-machine system scenes on computers for interactive ergonomics and design problem solving. As a fundamental research area, digital human modeling refers to the development of mathematical models that can predict human behavior in response to minimal command input and allow real-time computer graphic visualization.

Human capabilities, requirements, and performance are represented in these simulations through the use of digital human models, representing human size, shape, strength, vision, and movement as they interact with virtual geometry and environments. DHM are now widely used in the design of products, particularly aircraft, cars, trucks, and other vehicles. Industrial manufacturers are also increasingly using DHM to simulate workers in computer simulations of new plants or processes. In spite of these successes, the use of DHM has been hampered by the lack of fast, accurate, and reliable posture and motion simulation. Until recently, simulating a task that would be very simple for a real human, such as walking to a shelf and picking up a tool, required the ergonomics analyst to perform time-consuming manual posturing of the figure at each critical transition in the motion.

Using this process, known in animation as key framing, the skilled analyst requires many hours to create a simulation of a manual activity that would take a few seconds for a person to perform. Yet this process does not necessarily provide accurate postures or motions, dependent as it is on the analyst's judgment as to how a person would perform the task. Moreover, the analyst must often redo much of the work if the environment is changed or the characteristics of the virtual human (such as body size) are altered. The extremely time-consuming nature of key frame animation presumably creates a substantial incentive to develop predictive tools.

Ergonomics background

Ergonomics is the study of people at work and the practice of matching the features of products and jobs to human capabilities, preferences, and limitations. Industrial ergonomics focuses on ensuring that jobs are designed for safe, comfortable and efficient work. Ergonomics is also an important consideration in the design of products for maintainability and disassembly for recycling.

Industrial ergonomics is moving away from a reactive approach, in which jobs that cause injuries are modified, to a proactive approach that emphasizes assessing each job for feasibility and safety as the workplace and processes are

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designed. Some aspects of job design can be reduced to a checklist or a set of numerical criteria: maximum weight to be lifted or a maximum part insertion force. But when the potential problem includes an awkward posture or a difficult reach, a more complex analysis is necessary. Software representations of humans, known as digital human models (DHM), are becoming widely used to perform the analyses for these complex situations.

Need for DHM

As we expect new products to be designed and manufactured in a short time frame, and demand a high level of convenience, comfort, and safety, the capabilities to create a digital human with specific population attributes and merge it with 3D graphic renderings of proposed work environments are much desired. Speed of implementation requires that these designs be constructed in a virtual world. Digital human models are required for these virtual worlds for the exploration of vehicle and manufacturing designs from an ergonomic perspective. Considering the design and production of a new vehicle, it must be built and used by humans, so the design must accommodate a wide range of heights, strengths, ages and so on. On the product side, we must ensure that the customer can perform all the necessary functions in a safe and comfortable manner, while, on the manufacturing side, we must ensure that large volumes of the vehicle can be made within the capabilities of a wide range of workers.

Years ago, manufacturers could build a sequence of prototypes and use these to discover and rectify any problems. But now competitive pressures mean that the time to bring a vehicle to market is greatly reduced. Automotive manufacturers aim to produce the design for a new vehicle and the manufacturing facility to build it in an entirely virtual world. This speeds the introduction of the new product, but it does mean that designers must aim to anticipate any ergonomic problems before a physical build of the vehicle is completed or a new production facility is built. Experience with similar vehicles produced in the past is useful, but new vehicles have new features that may require design modifications. For these reasons, we need models that predict how humans of different types will behave in vehicle and workplace environments. We can then experiment with different virtual humans in the vehicle or production environment to detect any ergonomic problems and suggest appropriate design modifications.

One important aspect of human behavior that is relevant to ergonomic analysis is volitional, task-oriented movement. As can be readily seen, there is substantial variation in the way that people move that depends on their physical size, gender, age and other factors. There is also natural, but unexplained, variation in human movement. Predicting human motion and modeling this variation is a task for which statistical methods can be useful. For example, digital human models have proved useful in the design of retail stores so that wheelchair users can comfortably use the checkouts, both as customers and sales assistants.

DHM Technology

A digital human model is created by inserting a digital representation of the human into a simulation or virtual environment; this is then used to explore issues of safety and/or performance. The model enables researchers to visualize situations of interest, and the virtual environment incorporates all of the necessary mathematics or science to ensure rigor. Perception- based safety design applies fundamentals of human factors and ergonomics to the optimal design of products and processes in various application domains, including manufacturing, automotive, military and healthcare.

Traditional anthropometry using simple tools, like calipers and tape measures do not provide unique description of the body shape and are also subject to human errors. With the development of 3D laser scanning technology, it is now possible to capture the entire body surface. With the goal to analyze the variability of the human body shape, statistical shape analyses are performed on various 3D anthropometric databases. The main modes of variation extracted from a small number of principle components, correspond to our intuitive body characteristics such as height, weight, muscularity, etc. Analyzing and visualizing these variations form the foundation of many applications such as designing of clothing, helmets, masks, and other products that fit the human body better. It may also help build shape priors that can be used for reconstructing, recognizing, tracking, and animating human shapes. The virtual interactive design projects give consideration to both cognitive and physical aspects of the virtual interaction. Motion capture is then integrated with virtual reality as an input to some commercially available computer-aided ergonomics models.

Applications of DHM

The largest area of application for digital human models is in vehicle design. Expensive physical mockups are being replaced with virtual prototypes that are assessed using virtual drivers, passengers, and maintainers. The implementation of digital human modeling technology allows easier and earlier identification of ergonomics problems, and lessens or sometime even eliminates the need for physical mock-ups and real human subject testing.

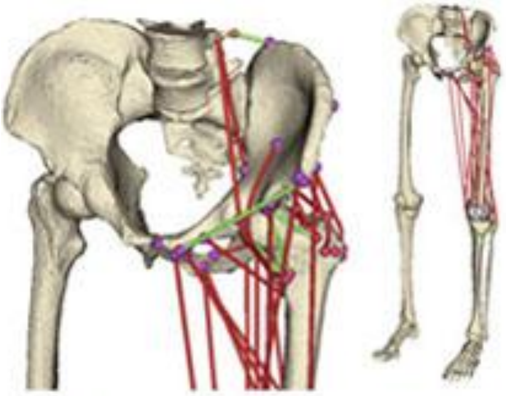
Opportunities for the systematic application of engineering principles to healthcare delivery include simulations and predictions of healthcare outcomes. By considering human physiological and psychological factors during virtual interactive design, the likelihood of injury or error given certain workplace conditions and task requirements can be determined.

Human motion modeling is also used in a range of other areas such as sport, neuroscience and movie and video game production. For example, in current video games, the characters perform motions from a limited and precalculated library of motions due to the demands of real-time performance. In feature films, commercials, and video games, nearly every movement of a computer-generated character is produced by playing back motion data obtained from a human actor, possibly after modifying or "warping" the motion.

Future Scope

With the computing power and computational methods available today, we are able to render digital human models that are an order of magnitude more sophisticated and realistic than the ones produced a decade ago. There is however still a long way to go before we achieve the "ultimate" digital human surrogates- ones that look, act and even think like we do.

Development of future DHMs including valid posture and motion prediction models for various populations to improve the physical design of vehicle interiors and manufacturing workplaces will ensure real motion data to assure validity for complex dynamic task simulations.



It is further speculated that if valid human posture and motion prediction models are developed and used, these can be combined with psychophysical and biomechanical models to provide a much greater understanding of dynamic human performance and population specific limitations and that these new DHM models will ultimately provide a powerful ergonomics design tool. Additional research leading to new models will provide more robust predictions, including consideration of the dynamic aspects of work for improved safety and risk predictions.

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