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DENEB/ERGO — A SIMULATION BASED HUMAN FACTORS TOOL

Narinder Nayar

Deneb Robotics, Inc.
3285 Lapeer Road West
P.O. Box 214687
Auburn Hills, MI 48321-4687, U.S.A.

ABSTRACT

The Deneb/ERGO software is an interactive, 3D simulation-based tool for human factors and ergonomic analysis. The tool is very useful for workplace design and analysis, allowing the user to rapidly prototype human motion within a work area, using a graphical motion programming paradigm. Capabilities are provided for developing time standards and studying the ergonomics of a job related to lifting, energy expenditure and posture analysis using percentile based, fully articulated 3D human models. The presentation first focuses on the need for such a software tool and then discusses the various motion programming and analysis capabilities of the software.

1 THE DENEB/ERGO SOFTWARE

1.1 The Need for Simulation-based Human Factors Software

The design of workplaces, equipment and complex mechanisms can only be done after examining the inherent "human factor" in the design process. Industrial engineers and designers have traditionally relied on costly and time-consuming mock-ups to evaluate their designs and workplaces. To avoid costly "fixes" in the manufacturing stage, it is important to evaluate available alternatives early in the design stage. Most human factors software tackles only a specific area related to Human Factors and Ergonomics, be it human motion, reachability, anthropometry, biomechanics, standard motion times, or ergonomic analysis. Deneb/ERGO is a combination of all these perspectives. Using Deneb/ERGO results in significant reduction of effort for the designer, since all the data, analysis and functional parameters are resident within a single, comprehensive software package. The user no longer needs to use one software for motion prototyping and another for analysis. Rather, cause and effect relationships can be interactively examined within the same software tool.

1.2 The Simulation Environment

One important distinguishing feature of Deneb/ERGO software is its simulation environment. In addition to prototyping human motion, Deneb/ERGO allows the user to realistically model moving entities that a human interacts with in real life. This feature becomes even more important when using Deneb/ERGO as a visualization and training tool to ensure workers perform their job as designed.

Deneb/ERGO is an option to the IGRIP® and ENVISION® simulation software products. The mature core technology of the simulation software provides a user-friendly environment with the following functionality: (a) fast, interactive 3D graphics; (b) integral, complete 3D CAD system; (c) configurable color graphs that display cycle information; (d) dynamic viewpoint manipulation with multiple view points that can be independently controlled — including the ability to attach a camera to any moving or stationary part; (e) realistic lighting models that provide the ability to display shadows, colored lights, and part secular highlighting; (f) advanced file management system featuring a Visual File Interface that facilitates the association of an image with a file, enabling files to be selected by either clicking on an image or file name; (g) a real-time system for collision, near miss, and minimum distance checks.

1.3 The Features of Deneb/ERGO

The Deneb/ERGO functionality includes: (a) a dedicated human motion programming interface that includes inverse kinematics and graphical programming for human models; (b) 5, 50 and 95 percentile male and female models; (c) an energy expenditure prediction model; (d) guidelines for two-handed lifting; (e) a Posture Analysis System; and (f) a work-measurement standard to estimate time standards for jobs.

The features of IGRIP or ENVISION and Deneb/ERGO combine to provide the user with a versatile, flexible and powerful tool for human factors engineering.

1.4 The CAD Interface

Deneb/ERGO includes a fully-functional 3D CAD system. This allows the user to either create desired geometry rapidly or use the CAD data translators such as IGES, Pro/ENGINEER, Unigraphics, DXF, STEP, CATIA and VDA to import existing geometry. Data reduction facilities are provided to simplify or modify geometry to enhance graphics performance. Furthermore, existing geometry can be scaled and stored on the hard disk to build libraries of tools/parts that are commonly used in the working environment.

1.5 The Virtual Reality Interface

Deneb/ERGO supports the latest in Virtual Reality devices, such as the FakeSpace Boom, data gloves, helmets, and StereoGraphics eyewear. Users can immerse themselves within a workcell to virtually walk through and examine it.

2 THE WORKER MODEL

In Deneb/ERGO, the human model is referred to as a worker. The worker model inside the computer is an articulated representation of the human body. The worker has 50 degrees of freedom, which is more than adequate to represent the major joints in the human body. The number of degrees of freedom can be increased up to 128 by the user to model a fully articulated hand, for example. The user can also change workers with varying anthropometry to design a workplace for a certain range of workers, rather than just one. 5, 50 and 95 percentile male and female models are available with the software.

3 THE HUMAN MOTION PROGRAMMING INTERFACE

Before utilizing the software's ergonomic analysis functions, the user must teach a worker the designed job. The teaching process is done through a dedicated human motion programming interface. This is an user-friendly and intuitive interface, which provides utilities to manipulate the human body joints. Tasks such as walk, stoop, squat, bend, and grab are accomplished in seconds.

The human motion programming interface is based on the *graphical programming paradigm*. One of the main objectives of this paradigm is to not burden the user with writing extensive Graphic Simulation Language (IGRIP's simulation language) programs to govern the action and motions of the worker. In this paradigm, the user teaches the worker motion sequences. A motion sequence is an ordered collection of postures where the user manipulates the worker's limbs using task-based and graphical programming. The system does not remember the transient postures that the worker achieves while trying to get to a user-desired posture for the worker. The system only remembers postures that are explicitly stored by the user. A posture contains information regarding the joint values, attachments, and analysis. There is no limit to the number of postures in a motion sequence or the number of sequences attached to a worker. The interface also provides utilities to move forward and backward through postures for quick visual verification and editing of motion sequences.

The resulting inverse kinematics solution incorporates automatic torso bending and leaning to increase arm reachability limits. The shoulder rotation joint is kinematically redundant, meaning the joint rotates in a limited range of motion without affecting the final position and orientation of the palm. During inverse kinematics, the redundant shoulder rotation is also adjusted based on experimental results from neurophysiological studies to put the elbow in a "natural" setting. Utilities are provided to allow the taught worker to locate moving parts in the work area without having to reteach the motion sequence. These utilities also facilitate teaching tasks in a parametric way so that the same motion sequences can be used to test the desired range of population.

4 THE WORK MEASUREMENT STANDARD

For accurate performance analysis and rapid evaluation of alternative work methods, Deneb/ERGO comes with a work measurement standard. This module determines time standards for jobs to support efficient task planning. The results from these standards are used for either designing new jobs or improving existing jobs.

The standard implemented is MTM-UAS (Methods Time Measurement - Universal Analyzing System). This system is universally applicable to any batch production job. It is tailored toward high speed analysis and utilizes a moderately sized data base with seven basic motion elements: "Get and Place," "Place," "Handle Tool," "Operate," "Motion Cycles," "Body Motions," and "Visual Control."

The user input involves breaking down the motion sequences into motion elements specified by the MTM-UAS system. Nested motion elements are allowed in this implementation. This means that a motion element can be temporarily halted to start and finish another motion element. For example, a "Get and Place" can be temporarily halted with a "Body Motion" such as a walk. Once the user has divided a motion sequence into motion elements, the system will compute the path lengths so that the time required to complete a motion element is divided suitably over the postures. Then, the user can actually run his simulation using the MTM-UAS standard motion times.

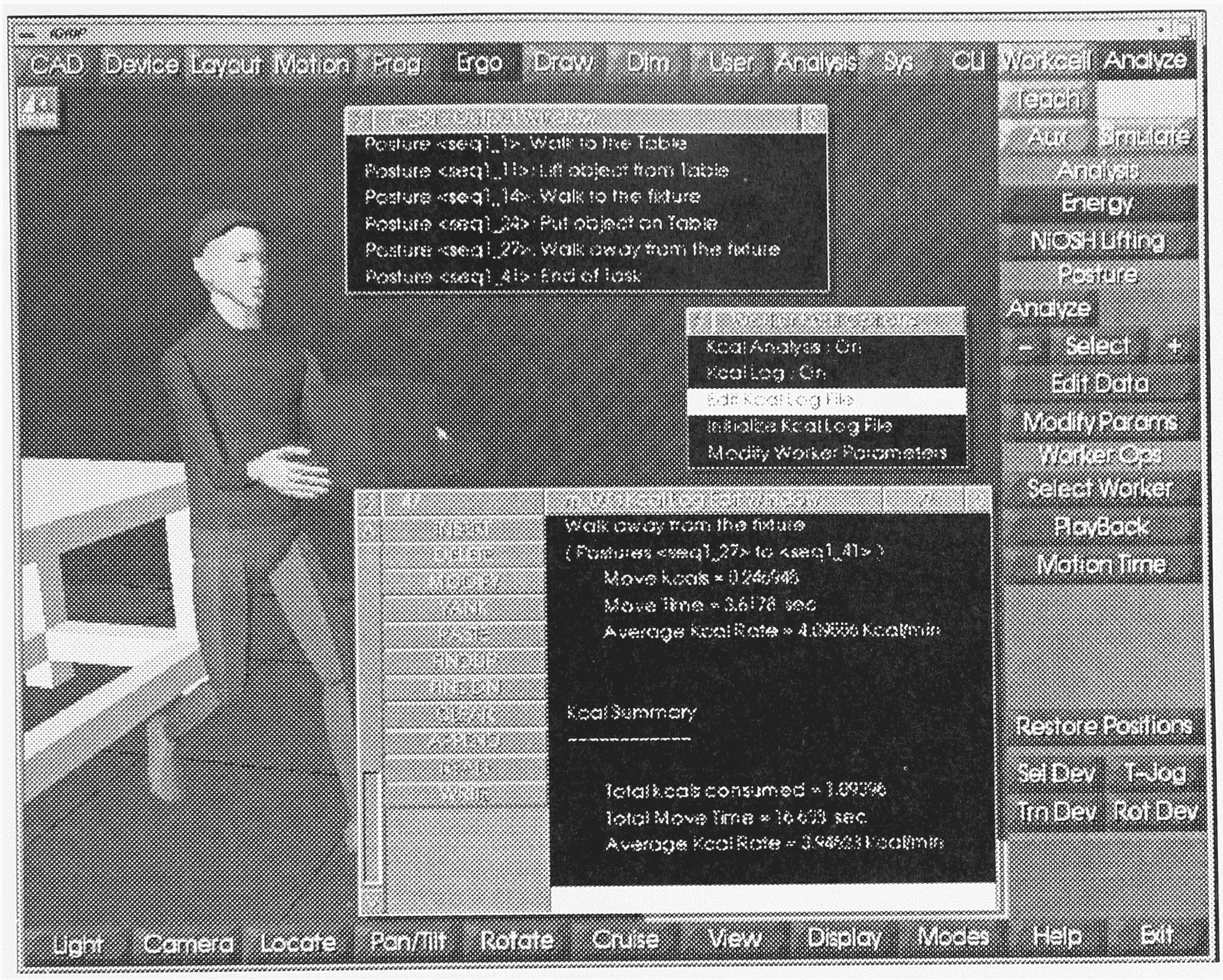

Figure 1: Energy Expenditure Using Deneb/ERGO

5 ERGONOMIC ANALYSIS CAPABILITIES

The following ergonomic analysis capabilities are included with the Deneb/ERGO software package:

5.1 The Energy Expenditure Prediction Model

As part of the ergonomic analysis capabilities available within Deneb/ERGO, an energy expenditure prediction model assures that the task being done is within a worker's capacity. The metabolic energy expenditure is a physiological measurement for determining the task intensity that can be continuously performed by a worker. By examining the energy requirements for a task, one can assess the capacity of the worker to do the task, establish duration and frequency of rest periods, and evaluate alternate work methods in case the task is too strenuous. The model can also be used to determine the effects of job rotation within a shift.

The implemented prediction model provides strong support for manual material handling activities that involve walking, carrying, lifting, pushing, or pulling. Some general categories for "Arm and Hand Work" are also provided for activities that are not covered in the prediction model.

The user input involves breaking down the motion sequences into the subtasks understood by the energy expenditure prediction model. Once the user has supplied this input, the system computes all the geometric distances from the simulation. The energy expenditure log from this prediction model is written in a report form to an ASCII file at simulation time. This log file gives a breakdown of the subtasks in the motion sequence(s) and the energy expenditure, the time and an average rate for each subtask. Towards the end of this file, it sums up the total energy expenditure, time, and averages the rate for all motion sequences analyzed (see Figure 1).

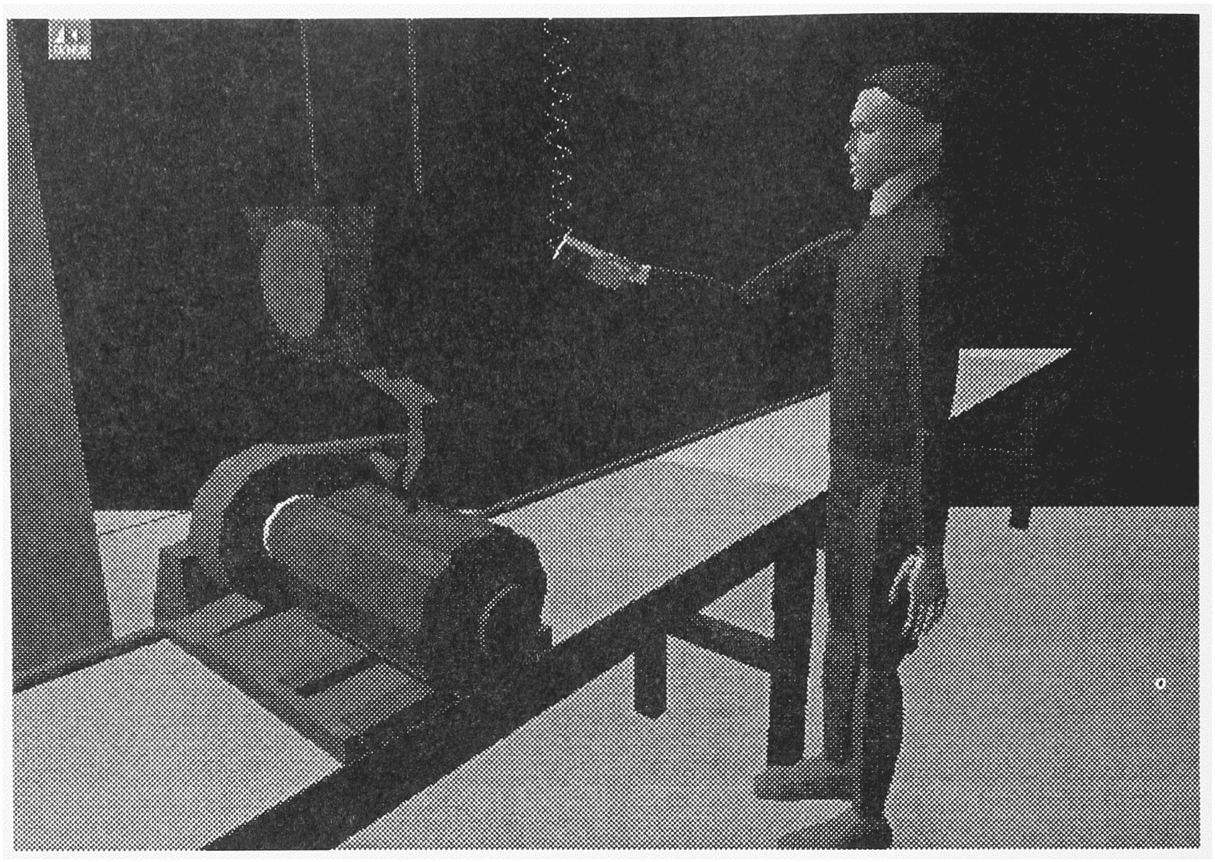

Figure 2: Analyze Two-handed Lifting Using Deneb/ERGO

5.2 Guidelines for Two-handed Lifting

Another ergonomic analysis capability that is available from this option is the implementation of the revised 1991 NIOSH (National Institute of Occupational Safety and Health) Lifting Equation to analyze the two-handed lifting activities of workers. This analysis is aimed at reducing low back injury and musculoskeletal disorders for workers involved mainly in two-handed lifting tasks. The output from the equation can help the user optimize workstation layout and decide if any lifting or assist devices are needed to help the worker perform the job without risk of back problems.

The lifting equation gives a measure of the human lifting capacity. The output of the equation is a weight limit suitable for men and at least 90percent of the women. The revised NIOSH equation sets this weight limit at 23 kg (51 lb) under ideal conditions, if all the lifting risk factors are 1.0.

Based on the user input of postures to indicate the starting and the ending of the lift, the Deneb/ERGO implementation of the Revised 1991 NIOSH equation calculates all the risk factors associated with the lifting task by computing the input variables from the postures. Based on the computed risk factors, the system outputs recommended weight limits for the lifting task. The weight limits are computed considering the risk factors both at the beginning of the lift and the ending of the lift.

The raw distance parameters, risk factors, and recommended weight limits are displayed in popup for the user. The system also allows the user to perform a "what if" analysis on the lifting task to determine the effect of job rotation requirements while adjusting the load location (see Figure 2).

5.3 The Posture Analysis System

Deneb/ERGO also has a posture analysis system. The implemented posture analysis system was developed to investigate the exposure of individual workers to risks associated with work-related upper limb disorders and to eliminate workplace hazards due to workstation configuration. The posture analysis system can be used to design a task for simulation-based training.

This posture analysis system examines the following risk factors: (a) number of movements; (b) static muscle work; (c) force/load; (d) working posture; and (e) time worked without a break.

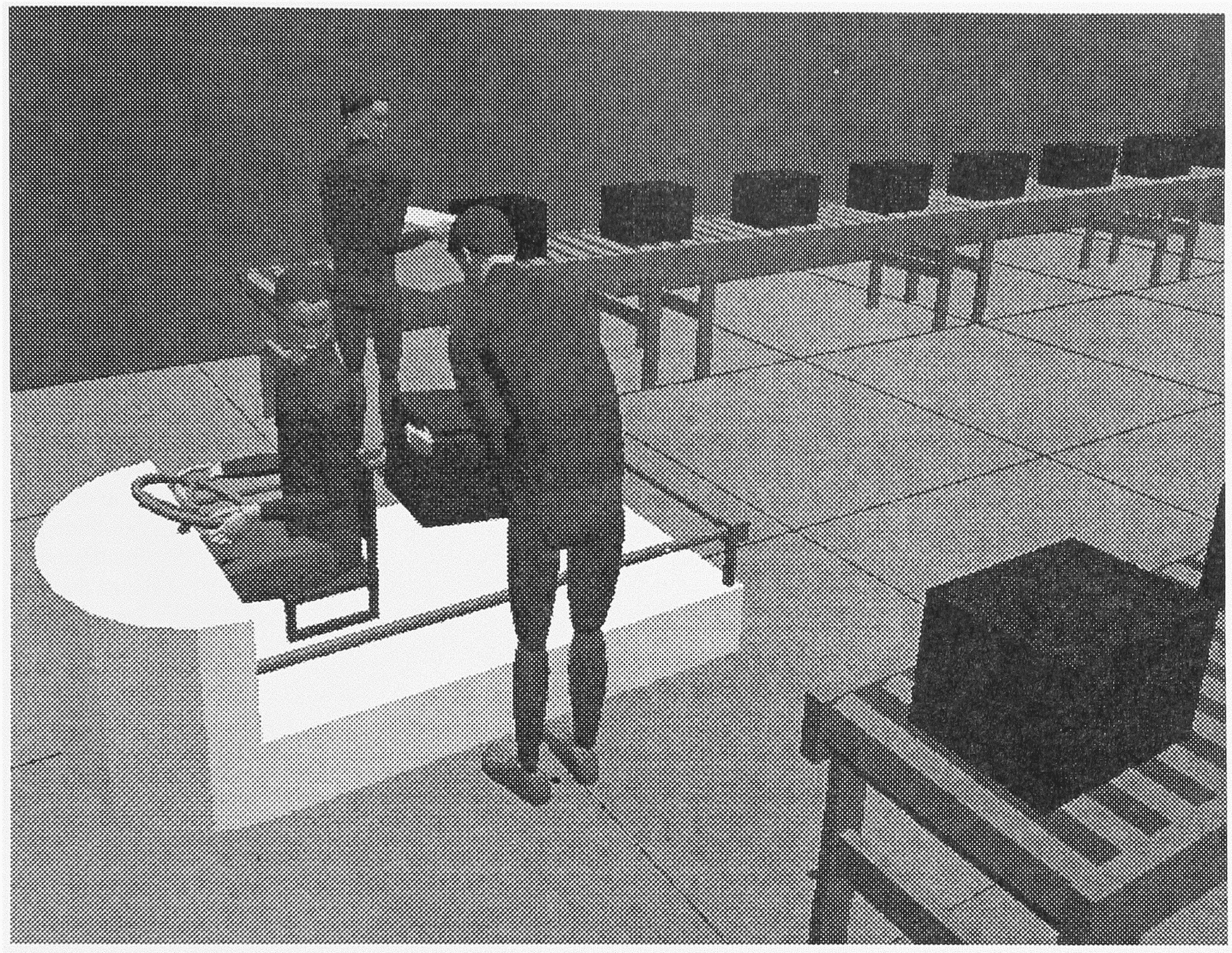

Figure 3: Human Motion Prototyping Using Deneb/ERGO

All these factors combine to provide a final score on the posture. For the working posture, the Posture Analysis system focuses on the use of arms and wrists and the orientation of the neck and torso.

The user provides input to the system regarding the muscle use and the loading on the arms and the body. The system combines this knowledge with the posture category (based on comfortable joint range of motion) to give an action level for the posture. The posture analysis can be used both during teaching the worker and at simulation playback time. At simulation playback time, this can be used to examine the working postures. More importantly, during teaching, the user can interactively correct and avoid poor postures while designing the workplace.

6 SUMMARY

The objective in creating Deneb/ERGO was to provide one software package that evaluates different perspectives for the human factors specialist. That objective has been met and the Deneb/ERGO is a decidedly a superior, flexible, and user-friendly tool that empowers the industrial design engineer and ergonomist with previously unavailable capabilities (see Figure 3).

AUTHOR BIOGRAPHY

NARINDER NAYAR is a senior software engineer at Deneb Robotics. He received his M.S. in Mechanical Engineering and Ph.D. in Applied Mathematics from the University of Virginia.