Computer Life (CPL) ISSN: 1819-4818
DELIVERING QUALITY SCIENCE TO THE WORLD

Overview of JACK Virtual Simulation Technology

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Abstract: This paper summarizes and analyzes the basic functions of JACK software. First, it introduces the functions of virtual environment, creating virtual human body and posture shape, positioning virtual human in virtual environment and assigning tasks, virtual human feeling evaluation and so on. Then introduce the TAT tool information, including lower back analysis, static strength prediction, lifting force analysis, etc.
Keywords: Jack software, tat tools, force analysis, software simulation.

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1. JACK SOFTWARE INTRODUCTION

JACK software was originally an intelligent software system developed by the Human Model and Simulation Center of the University of Pennsylvania after more than ten years. It is a software product in human factors engineering and is currently recognized as a more successful human body simulation simulation and ergonomics. Evaluation software. Using JACK software, the user can specify the completion of the specified tasks and perform corresponding simulation analysis, accurately define the digital human body of different sizes in the virtual environment and output related information, which is helpful for the product ergonomics design and man-machine Engineering evaluation and research.

1. Basic functions of JACK software

The basic functions of JACK include constructing a virtual environment, creating a virtual human body, defining the size and shape of the human body, positioning the virtual human in the virtual environment, assigning tasks to the virtual human, and performing virtual human sensory evaluation.

2. Virtual environment

The central working area of JACK is called the main scene, and all the environment and object models of the software are carried out in the main scene. In the main scene, different perspectives can be displayed through four scene modes: perspective view, top view, front view, and left view. When you need to adjust the model in the scene, you can adjust the size, position, material, lighting and other properties of the object through different viewing angle windows. The situation in other windows also changes while adjusting. Another function of the perspective view is to adjust the distance between the object and the observer in order to modify the details. In addition, JACK provides two presentation modes: camera mode and human perspective mode, which are used to simulate the observation of other models from different objects in the scene.

The coordinate system of the JACK system has two descriptions: the world coordinate system and the local coordinate system. The world coordinate system can determine the position coordinates of the object in the global scene relative to the entire simulated world. The world coordinate system of the object is relative to the entire scene, and the model The size and corresponding distance of is also determined by the value of the world coordinate system. The local coordinate system is established on the object model itself, and changes with the transformation of the object model. When it is necessary to adjust the position, direction and other attributes of the object, the local coordinate system should be used as the reference system.

JACK provides a set of object model library diagrams, which can be directly called from the tool library. Using these original models, a complete factory environment and work scene can be established.

Light is a special object in the JACK software object model. It not only has the properties of ordinary objects such as quality, surface, and material, but also has the characteristics of light form, color, brightness, and contrast. When there are requirements for lighting in a virtual scene, you can set the lights to simulate the light exposure and illuminance in the real environment

3. Create virtual human body and pose shapes

JACK provides an accurate human body model. The size measurement data of the human body model is obtained from the results of the US military's anthropometric survey in 1988. JACK's man-machine analysis is based on real human body data, and its human body model has actual anthropometric characteristics. The built-in ANSUR database of the software can meet most of the needs of scientific analysis and simulation. However, in practical applications, due to the differences in the size and appearance of the human body in my country and the Americans, the ANSUR database cannot represent the characteristics of most human body sizes in my country, and the size of the model must be redefined when using it. The advanced human body scale panel allows users to create custom people, define specific human body sizes and specified ages, and create digital human body models that meet research needs. When a digital human body model is selected, all its measurement information will be displayed on the panel. In the advanced anthropometric feature definition function provided by JACK, we can adjust each part of the body according to the actual situation of the Chinese to meet the actual requirements of simulation.

In addition to the well-defined standard human body model, JACK provides a powerful custom function, which can adjust the position and structure of segments, faces, and even nodes to determine the shape of the model during simulation. In JACK's model system, the smallest unit that composes the human body model is a node, multiple nodes form a surface, and the surface is combined to form a segment, and finally the segments form different objects and human models. Each model segment has parameters such as material, quality, local coordinates, size, etc., which can be modified by users as needed. Between the human body model and the nodes, there is a basic connection structure, which is the skeleton diagram, and the specific joint positions and partial structures can be displayed. This skeleton structure is simplified based on the main bone and joint activities of the actual human body. The virtual human body can be manipulated by directly changing the position of the bones and the degrees of freedom of the joints. And the JACK system provides more than 20 common actions and postures, including running, walking, pushing and other common actions.

4. Position the virtual person in the virtual environment and assign tasks

In JACK, there are two ways to set the posture of the virtual human body: directly manipulating the joints and choosing from a library of predefined postures. Moreover, the actions of the virtual human can be driven by setting the behavior parameters to make it move automatically according to the defined parameters. JACK's constraint system can be used to define the relationship between the virtual human model and the environment, and to define the constraints between the human body and objects in a variety of ways.

At the same time, there are also types of anthropometric evaluations that can perform ergonomic research only in a static posture. When the research needs to be dynamic, the human body movement can be set through the software's built-in movement system and virtual reality tool interface. You can precisely control the movement of each part by creating corresponding actions. When a simulation is created, it can be saved and played back. In addition, you can also change the environment by adjusting the size or position of various objects, and re-run the simulation to study the changes in spatial relationships, time and gaps. And JACK allows the use of virtual reality tools to create real movements for simulation research.

5. Virtual human feeling evaluation

JACK provides a variety of tool analysis packages that can be used for ergonomics evaluation and human factor analysis. At the same time, JACK software also divides the analysis function into two modules according to the different functions: the task analysis module for human factors and the analysis module optimized for machine design. The man-machine analysis toolkit provides 5 analysis tools to study the optimization of man-machine performance and comfort. The task analysis toolkit can evaluate the ergonomics and safety characteristics of the workplace, and perform work tasks on this basis. Optimize the design to maximize worker safety

Use JACK's task analysis tools to perform energy metabolism analysis, fatigue/recovery time analysis, lower back spine force analysis, manual handling restriction analysis, lifting analysis, working posture analysis, predefined time analysis, rapid upper limb assessment and strength Expect to wait.

2. TAT TOOL INTRODUCTION

1. Lower back analysis

Lower back analysis tool (Lower Back Analysis) is an analysis tool that uses advanced and complex physiological lower back models to calculate the pressure at the L4/L5 spine. By comparing the calculated results with the pressure standard value provided by NIOSH, it is judged whether the simulation task will increase the probability of lower back injury of the worker. At the same time, the analysis results will also show which tasks need to be improved in terms of human factors, so as to optimize the production layout to reduce the risk of workers' lower back injuries.

The lower back analysis operation is simple, and only a few steps can be completed for a handling task. The operation process includes the following aspects:

First, import a digital human body model into Jack, and adjust the posture of the digital human body to make it in the carrying state. Import the object to be carried by the digital person, set its relationship with the digital person, and make the weight of the object act on the digital person's hand. Simulate the process of human carrying objects. It can be static posture simulation or dynamic process analysis.

The lower back analysis tool will provide an analysis report and chart to show the analysis results, as shown in Figure 2.3. The analysis results include the following information: The pressure at the L4/L5 spine, the result of comparison with the standard value recommended by NIOSH, the upper body gravity and the weight of the carrying object, the torque of each joint at the L4/L5 spine, and how the trunk movement is The spine torque is balanced.

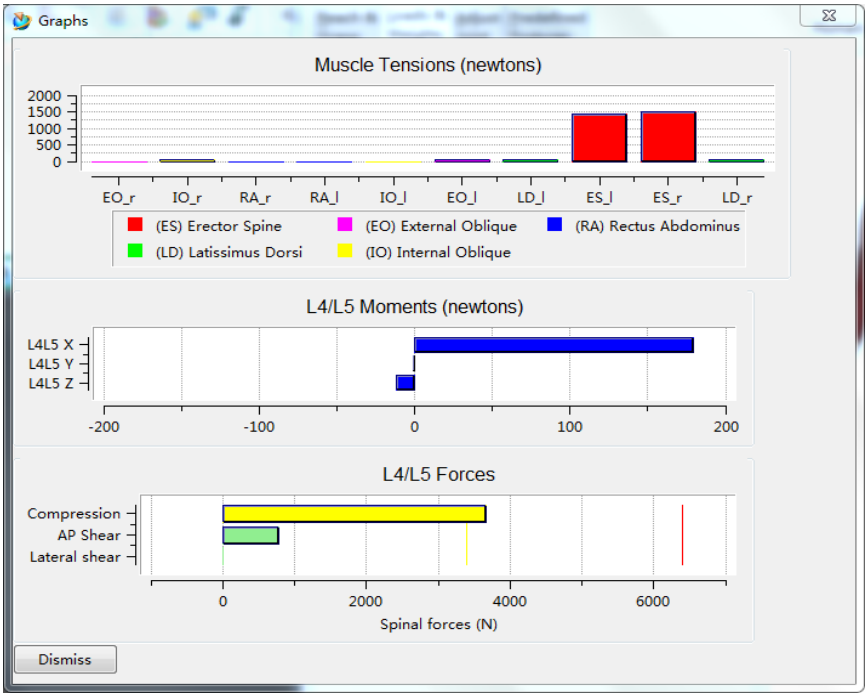

Fig. 1 Lower back analysis result chart

2. Static strength prediction

Static Strength Prediction is an analysis tool that evaluates how many percentile workers can maintain a certain working posture from a dynamic perspective. Static strength prediction adds Lifts, Lowers, Pushes, Pulls, etc. for complex hand force analysis and trunk twist analysis.

The following analysis results can be obtained through static strength prediction:

The percentage of workers who can complete work under this strength of the posture. The bending angle of each part and the torque and torque effect on the muscles (relaxation, tension, extension, and contraction) of the upper limbs and body, and the average and extreme values of the number of people at each intensity.

3. Analysis of lifting force

The lifting force analysis is mainly to evaluate the human factors in the lifting task, and provides the estimation of the physical strength of the free-hand handling task and the mechanical auxiliary handling task. Thereby designing new free-hand handling tasks or redesigning auxiliary handling machinery.

The handling index (LI) is an important indicator of handling analysis. When LI is greater than 1, it means that the current working state may cause harm to workers; when LI is greater than 3, it means that the current working state has a great probability of causing harm to workers. By calculating the handling index of the task and comparing it with the standard, it can be understood whether the worker

is a reasonable action during the work process, thereby avoiding or reducing the worker's physical injury.

4. Metabolism analysis

Metabolic Energy Expenditure (Metabolic Energy Expenditure, abbreviated as MEE) is an analysis tool that describes the physiological and working conditions of workers. The analysis can obtain the energy consumed by the metabolism to complete the task. Through the metabolic analysis of the existing work, it is possible to know whether there will be fatigue injuries, and also to obtain the most significant factors affecting energy consumption, so as to obtain methods for reducing work energy consumption.

The power to support the body during work is obtained by the body's decomposition of food, and the food is decomposed in the human body and releases energy. The process of energy production and consumption is called energy metabolism. Because the human body needs oxygen to participate in energy metabolism, energy metabolism can be quantified by oxygen consumption. The unit of energy metabolism is generally kilocalories, and the energy consumed per unit time is called energy. Consumption rate. Energy consumption, oxygen consumption, heart rate, and sweating during human labor can be used as indicators to evaluate the intensity of the task. Energy consumption can be divided into three types according to the state of the human body: basic consumption; quiet consumption; work consumption.

The basic consumption is the energy consumed by the human body to maintain the human life state when the human body is in a relaxed state. This is the energy that the human body must consume. The basic consumption of the human body is different in different environments. In order to be unified and convenient for calculation, The environment in which the basic consumption is located has been stipulated. The basic consumption conditions under this regulation are: the human body is lying quietly and awake, eating for more than 10 hours, and the ambient temperature is about 20 degrees. The energy consumption calculated under this condition is the basic consumption of the human body. It can represent the energy consumption required by the body to maintain the state of life, and in turn can reflect the body's metabolic level.

Quiet consumption is the amount consumed by the body in order to maintain body balance or maintain a certain working posture. Quiet consumption is basically measured by sitting on a stool to keep quiet before the work is done. Quiet consumption includes two parts, one is the basic consumption, and the other is the amount consumed by the human body to maintain a certain posture. Generally, the consumption of the human body to maintain a certain posture is about 20% of the basic consumption, so for the convenience of calculation, 120% of the basic consumption is generally taken as the value of the quiet consumption.

Work consumption is the total amount of energy the body consumes when completing a task or exercising. Work consumption includes three parts: basic consumption to maintain a life state, energy consumption to maintain a certain posture, and energy consumption during work. It can also be calculated by adding quiet consumption to work consumption. For a body, the value of work consumption is proportional to the work intensity. Work consumption can calculate the energy consumed by the human body in a day's work and the energy that the human body needs to replenish. It is an important factor in the assessment of worker fatigue.

In order to carry out the energy consumption of workers during work, related scholars have created an energy consumption prediction model. Through this model, the predicted value of energy consumed by workers during a certain period of time can be obtained. This predicted value can be used as a reference value for the degree of worker fatigue. This model decomposes a job into multiple tasks and actions, and the energy consumption of each task can be calculated by formula (5-1). The energy consumption prediction model consists of two basic components, namely basic energy consumption and task energy consumption. The process of energy estimation needs to know the information of each task, such as force, moving distance, frequency, task posture, etc. Ejob □ Ebasal□ EtaskjTtaskj (2-10) where Ejob is the average energy consumption rate of work (Kcal/min); Ebasal is the energy consumption rate (Kcal/min) for maintaining basic metabolism and posture (including standing, sitting and bending postures) min); □ Etaskj is the net metabolic energy consumption (Kcal) for completing the jth task in steady state; Ttaskj is the duration of completing the jth task (min). MEE mainly calculates the physical exertion of the person, and then judges whether the labor intensity of the work is too large.

The metabolic analysis tool first subdivides a task into several tasks, and then calculates the metabolic energy efficiency of each task through factors such as force, moving distance, frequency, posture, technology, weight, and cycle time of each task. 25 basic tasks include arm movement (manual), carrying (carrying), standing (standing), walking (walking), lifting (lifting), sitting (sitting), pushing (pushing), bending (bending), pulling (Pull), lowering (put down). The parameters defined in the task include force of load (load), time (time), distance (distance), slope (slope), initial and final position of the worker (start and end position) and frequency in the job cycle (work frequency). The operation process roughly includes the following aspects:

Import a digital human model into Jack and set the basic parameters of the digital human;

Define a duration for the job to be evaluated;

Estimate the proportion of digital people in various postures such as standing, bending, and sitting during homework;

Input the basic parameters of the job segmentation task into the analysis tool.

5. Fatigue recovery analysis

Fatigue and Recovery analysis tool (Fatigue and Recovery) can analyze whether the work process gives workers enough rest time to relieve fatigue. By calculating the rest time required for each job and comparing the actual rest time. If the actual rest time is shorter than the calculated rest time, it means that the worker may be over fatigued. By analyzing the fatigue caused by a posture or a set of continuous actions of a worker, the work process and equipment can be improved, and the time of rest during work can be found, and the work with the least fatigue can be formulated for employees.

The fatigue recovery analysis tool uses the static physiological model to obtain the torque experienced by the muscles to calculate the recovery time required for each task. When using tools, basic operations include the following:

Arrange a certain intensity posture for the digital person in Jack. In addition, you can change the posture or run a whole set of actions in the form of simulation;

Define the load on the digital person according to the actual work situation;

Define the duration of each task based on the actual work time.

6. Work posture analysis

Working posture analysis is an analysis tool that can quickly check the working posture. It can evaluate the discomfort of the working posture of various load-bearing parts under different loads. Assigning instructions to take corrective measures to assess the urgency of posture scores, so as to quickly assess the possibility of a certain work posture causing damage or injury to workers, design new jobs or improve existing jobs, to obtain a more comfortable workplace and more High-quality production quality. It can also determine the work posture most in need of improvement to meet ergonomic requirements.

For a specific posture and load requirement, the tool will assign a "correction need" level. After setting the working posture, the tool evaluates the posture according to the position of the back, arms and legs. The back position is divided into four options according to the degree of bending and twisting, and the arm position is divided into three options according to the level of the shoulder. The position is divided into seven options according to whether the person is sitting, standing, kneeling, walking, bending or straightening.

The analysis results of the work posture analysis tool can be used to design a minimum risk of work posture discomfort. For the specified posture, the tool will analyze the posture according to the relevant parameter requirements. The analysis results are divided into four levels, namely:

Level 1: The posture is normal and does not need to be corrected;

Level 2: Posture may have certain adverse effects, but no immediate action is required, and adjustments can be made in the near future.

Level 3: Posture has adverse effects and should be corrected as soon as possible;

Level 4: Posture is very harmful and must be corrected immediately.

7. Manual limit analysis

Manual Handling Limits analyze the maximum pressure that each percentile worker can withstand when working under various pressures, including lifting, lowering, pushing, pulling, and handling, and clarifying how to reduce the risk of lower back injuries. Analysis helps to design new jobs or improve existing ones, and find out whether the job will cause too much stress or too few workers to bear the workload.

The manual operation limit analysis tool operation process includes the following aspects:

Define the type of analysis work, which is divided into lifting, lowering, pushing, pulling, and carrying, and then define the parameters of the worker's gender and task;

In lifting and lowering tasks, it is necessary to define the width and shape of the operating object, the lifting distance, frequency, height, hand extension, etc.;

In pushing, pulling and handling tasks, it is necessary to define the handling distance, height and frequency;

Clearly define whether to estimate the maximum load that a certain percentage of workers can bear, or to find the percentage of the number of employees who can work under a certain load.

Hand-operated limit tools can perform two calculations: on the one hand, it calculates the maximum load that workers can withstand at work, and on the other hand, it calculates the proportion of workers who can complete a particular job. When a certain percentile is specified, the tool can calculate the ultimate load of work under that situation. For example, what is the load that the x-percentile workers

can bear; when the limit load is given, the tool can calculate the percentage of workers that can work under that load. For example, what is the percentage of workers who can work under load x; when the task time exceeds 8 hours, the tool will automatically determine whether the work load exceeds the optimal load given by NIOSH.

8. Working time analysis

Working time analysis is an analysis tool that uses the MTM-1 system as a tool for measuring time. When measuring time, you need to divide a task into multiple small tasks, and then analyze each small task to measure the required time . When analyzing working hours, it is necessary to set the completion cycle of each task, as well as the manual work plan and the tools and auxiliary equipment that need to be used during the work. In the analysis, you can get the task that takes the longest time, formulate a new operation plan by improving these tasks, and compare the new plan to find the shortest cycle plan.

Working time analysis tool can subdivide a complete job into multiple actions, from stretching, moving objects, twisting, pressing down, grasping, positioning, putting down, releasing objects, sight, body, limb movements, etc. as tasks. Each action of is assigned a type. Define the parameters of each action, such as torque, force, object type, object moving distance, pressure, push and pull, torsion angle, position requirements, etc. Then use the action time measurement system to analyze the time consumed by each action, and finally get the work cycle.

9. Force analysis

The force analysis tool has the functions of static strength prediction and lower back analysis at the same time. Through this analysis tool, the digital person can be adjusted to a specific posture, and the force and action parameters of the digital person can be defined at the same time, and finally predicted The maximum force of the worker in this situation. Whenever the joint torque or lower back force increases by 1N, the force analysis tool will automatically calculate the force of the joint until the force exceeds the reasonable limit.

When using this tool for analysis, it is necessary to define the force, support, frequency and time, and force limit. When defining the force, you need to define the position and direction of the force on the left and right hands; support can define whether the digital person is supported or not when performing tasks. For example, in the case of force distribution, you can choose the way of supporting the lower limbs, standing or sitting to perform the task; frequency and time can define the frequency and duration of the task, so as to calculate that the digital person can bear the task at this time and cycle. What kind of pressure? The force limit defines the maximum force a worker can bear. Generally, the parameters here are not changed because these parameters are defined by international organizations.

The main data and conclusions of the force analysis can be obtained from the Ergonomics Analysis column. Pay special attention to the color in the table. When the force changes, the color in the table will also change. Among them, red means that the action cannot be maintained and cannot continue to increase the force; yellow means that the force of this joint in this position has reached the limit at this time; green means that the force is acceptable and can continue to exert pressure.

ACKNOWLEDGEMENTS

This paper was supported by Optimization analysis of ergonomics of panel saw based on virtual simulation technology (S202011360047).

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