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A method for accessible domains computation and visualization in the case of using maintenance tools

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Abstract: A method for accessible domains calculation and its three-dimensional visualization is proposed in this paper, aiming at the shortage in accessibility analysis functions of the related simulation software when developing virtual maintenance in the case of using maintenance tools. Firstly, the size of virtual human's arm is computed according to its configuration structures. Secondly, a technique to calculate the farthest accessible distance is given with the information of tools' remote node point. The magnified scale is calculated by the distance value and the length of the virtual human's arm, and then the scale is utilized to realize visualization for the accessible domain in the case of using the maintenance tools. Finally, the accessibility analysis function mentioned above is implemented based on the Jack software with Tcl/Tk and Python programming languages. The simulation examples show that the proposed approaches satisfy the accessibility analysis in the case of using maintenance tools, and the automatic function that generates simulation reports will lower the burden of simulation personnel.

Key words: maintenance tools; accessibility analysis; accessible domains; graphical visualization; Jack simulation software

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0 Introduction

According to the Military Standard GJB/Z 91-97, *Maintainability Design Technique Handbook*, the accessibility is defined. It refers to the difficulty[1] of accessing the maintained part in product operation or maintaining. As an important analysis work of developing virtual maintenance[2-3] and man-machine engineering simulation[4], accessibility validation analysis is of great application value in the layout optimization of control cabin of car or airplane[5-8], the layout optimization of aeronautical environment control and life support cabin[9], virtual maintaining of spacecraft under the state of weightlessness[10] and other engineering problems. Generally, the research content of accessibility contains space accessibility, vision accessibility, operation space analysis, et al.[8,11]. In the practical virtual simulation validating process, accessible domain envelope is usually used for the qualitative analysis of accessibility of maintained part. The virtual maintenance object or the maintained part within the accessible domain envelope of virtual human is accessible. The above work mainly researches the accessibility analysis of virtual human under the condition of bare-handed operation.

In terms of the maintenance simulation of complex devices such as ships, maintenance tools are generally needed for finishing the relative operation in the virtual environment. Therefore, the accessibility analysis in the case of using maintenance tools is of great significance for the operation space design and analysis validation. However, the current popular simulation analysis softwares, such as Jack or Delmia, cannot provide the three-dimensional visualization analysis function of accesibility during the operation of tools, but only provide space accessibility analysis function of bare-handed operation. It is mainly studied in this paper about the visualization analysis

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method of space accessibility in the case of using tools. The main difficulty lies in: how to compute the accessible domains in the case of using tools (operation part) and display the three-dimensional visualization of accessible domains, and how to bind the geometric entity of accessible domains to the exact part of virtual human so as to develop the accessibility qualitative analysis for the users.

Based on the above application demands and technological difficulty, the accessible domains computation and its three-dimensional visualization methods in the case of using maintenance tools will be proposed in this paper. Firstly, the accessibility analysis flowchart and factors of maintenance tools are investigated and analyzed. Then, it is provided about the accessible domains computational method and the interface design scheme of accessibility analysis function in the case of using maintenance tools. Finally, combined with Jack simulation software, the accessibility analysis function can be realized.

1 Accessibility analysis flowchart and factor analysis in the case of using maintenance tools

After constructing the simulation model of maintenance object in simulation software and calling into virtual human, users need to call into maintenance tool model to the virtual scene from maintenance tool library or local, such as screwdriver, hammer, spanner and so on. In addition, the maintenance tools should to be adjusted to the left or right hand of virtual human, which generally adopts gripping action. Next, users need to move the virtual human in front of the maintenance object, and set a certain posture for the virtual human so as to make the remote node point of operation part of tool reach the maintained part as far as possible. Besides, the virtual human can be up-right, bending or with other postures. For the convenience of discussion, from the point of space accessibility analysis, the space accessibility in the case of using tools is defined as follow:

Definition: the maintained part is defined to be accessible when the remote node point of operation part of tool used by virtual human can reach the maintained part of simulation object and the virtual human has no hard interference with the maintenance object and the surrounding environment model.

In the above definition, Jack simulation software provides "Collision detection" function in the aspect of interference checking, which can realize the real time interference checking of one or one group of Segment with another one or one group of Segment. According to this function, the interference of virtual human with other objects can be determined. Through analyzing the existing references related to virtual maintenance, the accessibility simulation analysis steps and accessibility determination logic of tools can be described and presented in Fig. 1.

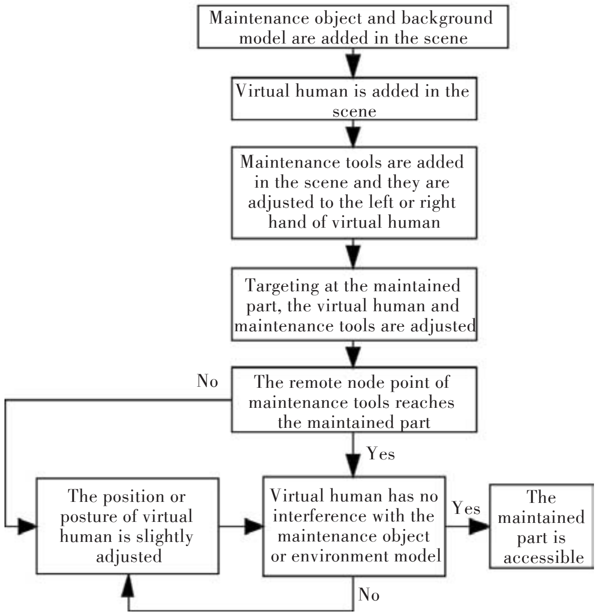

Fig.1 The determination logic for the accessibility analysis of maintained part

It can be noted from Fig. 1 that the factors of a complete accessibility analysis flowchart in the case of using tools are as follows: maintenance object and background model, virtual human, maintenance tool and its remote node point of operation part and the accessible domain geometric entity. From the perspective of function, maintenance object and background model as well as virtual human import are functions of Jack, Delmia and other simulation softwares. Besides, the functions of selecting virtual human and its left/right hand, computing accessible domain and generating three-dimensional geometric entity are in demand.

2 Design and realization of accessibility analysis in the case of using maintenance tools

Based on the research of accessibility analysis flowchart and factors in the case of using tools, the analysis interface and its function are designed in this section. Meanwhile, the computation of accessible domain and its three-dimensional visualization method are introduced. The design scheme and computation method are realized based on Jack software.

2.1 Accessible domain computation and its three-dimensional visualization method in the case of using maintenance tools

In terms of the accessibility analysis simulation factors, it is critical to know the way of computing accessible domain and picturing envelope geometric entity. Whether the maintained part is within the geometric entity can be qualitatively analyzed by applying this geometric entity.

The basic thought of this paper is: the farthest accessible distance *Dis_T* in the case of using tools, which is compared with the farthest accessible distance *Dis_none* of virtual human without using tools (bare-handed operation). The magnified accessible domain geometric entity of bare-handed operation is the accessible domain geometric entity in the case of using tools. When computing the farthest accessible distance *Dis_T*, it is drafted to add the arm size of virtual human to the distance from wrist to the tools' remote node point. Therefore, the functions of virtual human left/right hand selection and tools' remote node point selection are required when designing interactive interface.

The complete three-dimensional visualization method of accessible domains is presented in Fig. 2.

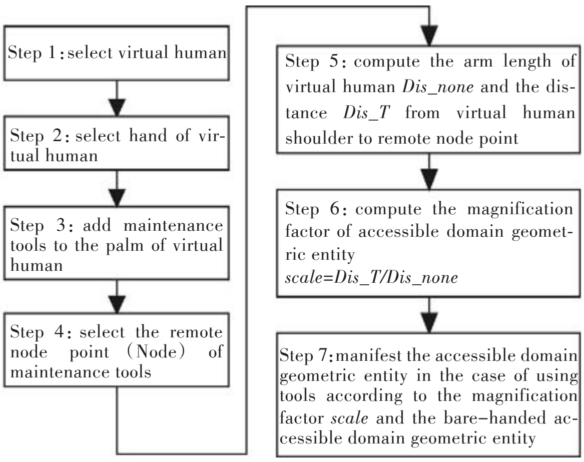

Fig.2 Computation flowchart for the accessible domain and its envelope

In Fig. 2, the computation method of the farthest accessible distance *Dis_T* when using tool is as follow:

$$Dis\_T = Len\_Arm + Len\_LowerArm\_Dis2T \quad (1)$$

where *Len_Arm* and *Len_LowerArm_Dis2T* refer to the arm size and the distance from wrist datum point (*LowerArm_Distal*) to tools' remote node point (*ToolNode*), respectively. And the computation methods are Eq. (2) and Eq. (3).

$$Len\_Arm = Len\_UpperArm + Len\_LowerArm \quad (2)$$

$$Len\_LowerArm\_Dis2T = dis(LowerArm\_Distal, ToolNode) \quad (3)$$

where $dis(a, b)$ in Eq. (3) refers to Euclidean distance between two points. In Fig. 2, the computation method of the farthest accessible distance *Dis_none* of virtual human with bare-hand operation is as presented in Eq. (4).

$$Dis\_none = Len\_Arm + Len\_Hand \quad (4)$$

where *Len_Arm* and *Len_Hand* are arm size and palm size respectively. The computation method of arm size is the same way as above. The computation method of palm size is showed in Eq.(5).

$$Len\_Hand = dis(LowerArm\_Distal, HandNode) \quad (5)$$

According to the results of *Dis_T* and *Dis_none*, the magnification factor *scale* of accessible domain envelope geometric entity can be figured out in accordance with the computation method in Fig. 2. In this paper, the visualization of accessible domain is realized through magnifying the original geometric entity.

2.2 Accessibility analysis interface and function design

Synthesizing the above analysis, the accessibility analysis function interface as shown in Fig. 3 and Fig. 4 is designed and realized.

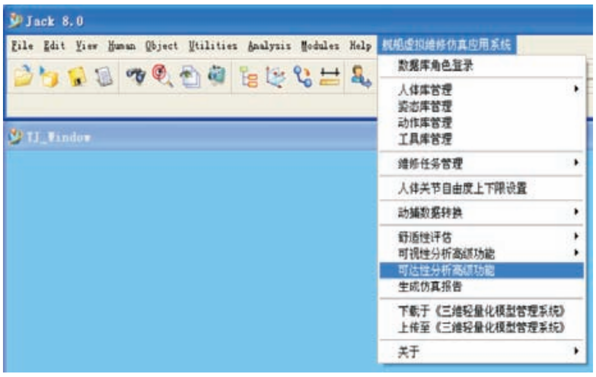

Fig.3 Accessibility analysis function menu in the menu bar of Jack 8.0

Fig. 3 shows the "accessibility analysis advanced function" sub-menu item of "virtual maintenance simulation application system" menu of Jack 8.0 menu bar. Fig. 4 presents the accessibility analysis interface when using tools, which includes virtual human selection, left/right hand selection, tools' remote node point selection, accessible domain generation, accessible domain selection, accessible domain edition (vitrification, wireframe, coloring and deletion), screenshot and report generation, opening report, etc. Among these functions, report generation and opening are designed for the convenience of authoring accessibility analysis report for simulation staff.

Fig.4 User interface of accessibility analysis function in the case of using maintenance tool

2.3 Realization of accessibility analysis function in the case of using mainte-nance tools

On the basis of Jack, the operation interface and function presented in Fig. 3 and Fig. 4 are realized through applying Tcl/Tk language combined with Jackscript and Python.

2.3.1 Realization of analysis interface

Firstly, the accessibility analysis sub-menu when using tools is added in the menu bar of Jack, generating the code of sub-menu in Fig. 3 as follows.

set auto_index(s7reachability) [list source[file join $dir s7_reachability.tcl]] # end of statement.

Besides, the following codes are added to the end of document jk.menu:

jkMenu create s7 "accessibility analysis advanced function" #;

jkMenu command s7 "accessibility analysis" {s7reach-ability} #end of statement.

The above codes accomplish the construction of interface in Fig. 3.

The interface and partial button functions in Fig.4 are programmed by Tcl and reserved in file jk2.0, named as s7_reachability.tcl. In addition, the codes of virtual human selection and tools' remote node point selection are as follows:

jsDUobjectSelector $fm0.selhuman "visual human selection:" _rcb_current, human-pickType human-objectPtrIndex current, humanPtr-pickOKCommand"rcb_selhuman" #end of statement.

jsDUobjectSelector $fm0.selnode "tools' remote node point selection:" _rcb_current, node-pickType node-objectPtrIndex current, nodePtr #end of statement.

2.3.2 Realization of accessible domain compu-tation and visualization

According to the information of virtual human (Human) and its left/right hand selected by user, the accessible domain of left/right hand is computed and visualized. Parts of the key codes and annotation are as follows.

#The code of computing the size of left hand is as follows. Note: the computation code of the size of right hand is similar to the following code.

fn='reachability_left.pss'

cl=human.segment.left_clavicle.lateral

xl=xyz(-0.043800, 1.607099, -1.570791)*

trans(-0.000001, 0.000001, 0.000004)

a0=74.488238513892583

a1=distance(human.left_upper_arm.proxi,

human.left_upper_arm.distal)

a1+=distance(human.left_lower_arm.proxi,

human.left_lower_arm.distal)

a1+=distance(node,human.left_palm.base)

The following refers to the key code of three-dimensional visualization of accessible domain.

fp=os.path.normpath(os.path.join(s7path,fn))

fig=scene.Load File(fp)

#compute the binding location of geometric entity:

fig.Set Location(xl*cl.Get Location())

Compute the magnified scale of geometric entity and magnify the geometric entity:

fig.Scale(a1/a0)

#bind geometric entity to the virtual human body:

fig.Attach To(cl)

Besides, the edition function is provided aiming at the generated accessible domain geometric entity, including: vitrification, coloring and wireframe manifesting, and deletion. Chapter 3 will validate the accessibility analysis function.

3 Simulation and analysis

3.1 Simulation case

Picking butterfly valve as the maintenance object, this chapter develops the validation of maintenance accessibility analysis when using tool. The specific examples and operation steps are as follows.

1) Start Jack. The maintenance model and maintenance devices (such as table) of butterfly valve are called in the simulation scene.

2) Select "ship virtual maintenance simulation application system"→ "accessibility analysis advanced function" in Jack menu bar. And the interface pre-

sented in Fig. 4 is popped out.

3) Select the icon of creating male/female virtual human in tool bar of Jack simulation software, generating virtual human automatically.

4) Select virtual human and its left/right hand: click the hand-shaped icon on the right of "virtual human selection" in the interface in Fig. 4. Then, the virtual human model in Jack simulation scene is clicked; after that, the radio button of left or right hand in Fig. 4 interface is selected.

5) Select tools' remote node point: first, the maintenance tools are called in, which can be from the maintenance tool library of "ship virtual maintenance simulation application system" or the tool model built-in Jack. The tools are bound with the left or right hand of the selected virtual human (screwdriver model built-in Jack is selected in this case); then, the remote node point Node of maintenance tool in the scene is selected by applying "tools' remote node point selection" hand-shaped selection button in the interface. And the scene is shown in Fig. 5.

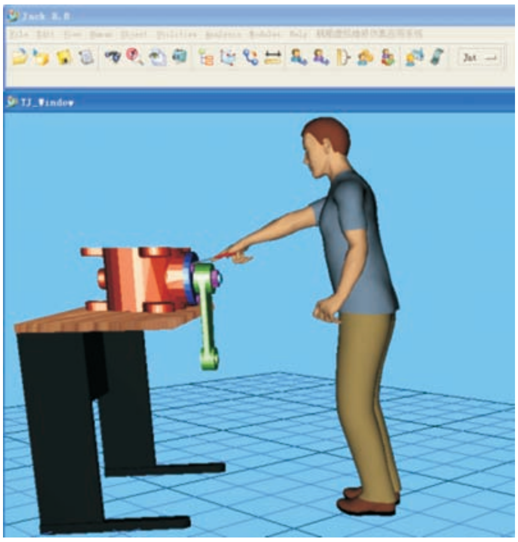

Fig.5 Screenshot of the accessibility analysis for butterfly valve

6) Generate the accessible domain: according to the selection result in 4) and 5), this function automatically computes and generates the accessible domain of virtual human when using specific tools, which is expressed by three-dimensional picture. The red geometric entity in Fig. 6 is the accessible domain of remote node point of screwdriver in the case of using screwdriver. It can be known that the butterfly valve in the geometric entity is within the accessible domain of screwdriver.

7) Select and edit accessible domain: the accessible domain geometric entity generated in 6) is selected, which can be edited, such as vitrification, wireframe manifesting, coloring manifesting and deleting this accessible domain geometric entity. Fig. 7 shows the display effect of vitrification.

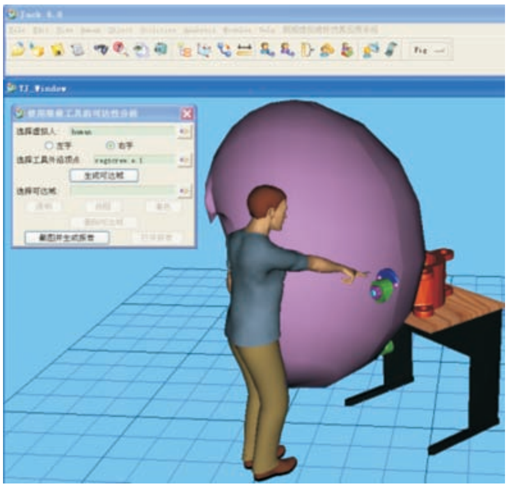

Fig.6 The geometric visualization effect of the accessible domain for the virtual human using screwdriver with right hand

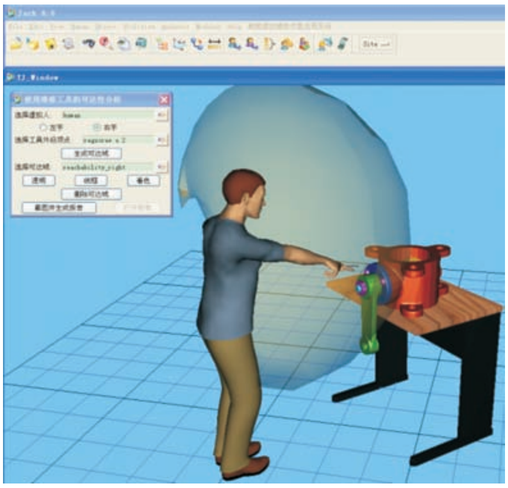

Fig.7 The vitrification effect of the accessible domain geometric entity

8) Screenshot and report generation: after selecting "screenshot and simulation report generation" button, the screenshot program is started automatically and generates accessibility analysis report, as shown in Fig. 8.

3.2 Analysis

It can be discovered from the above simulation cases that the realized functions satisfy the demand of accessibility qualitative analysis of using tool. When computing the farthest accessible distance, the tool and arm are implied to be in a line. Theoretically, the computed distance is the farthest and satisfies the demand of accessibility analysis when the maintenance tool and arm are in one direction. Other-

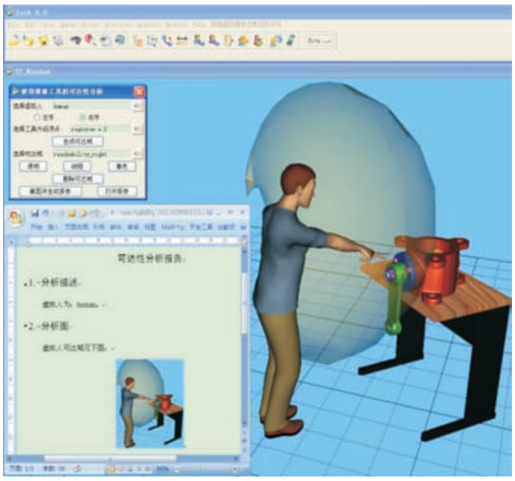

Fig.8 The automatically generated accessibility analysis report in the case of using maintenance tool

wise, the computed distance is shorter than *Dis_T*.

The future work mainly includes:

1) Combine VTK with OpenGL for realizing the real time drawing of geometric entity.

2) Combining the physiological features of human upper limb, point cloud data of accessible domain geometric entity surface can be obtained through adopting the scanning method in Reference[12] or other sampling methods, reconstructing the envelope of this accessible domain.

3) Combine the structure and physiological feature of human upper limb, the research on accessibility analysis method for constrained trunk or upper limb can be developed by applying forward kinematics, inverse kinematics and collision detection algorithm, which can provide technological support for the accessibility simulation validation of maintained parts with upper limb of human body limited by narrow space.

4 Conclusions

In order to solve the lack of accessibility analysis function in the case of using maintenance tools for simulation software, accessible domain computation method and three-dimensional visualization method in the case of using tools are proposed in this paper. Besides, the proposed methods are realized through combining Jack. The experiment result indicates that: the methods in this paper improve the existing software functions to a certain extent, which lays a foundation of further developing the accessibility analysis validation of maintenance operation in narrow space.

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舵系统的颤振计算与分析

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摘　要:为了研究舵系统水弹性特性,基于二元水翼线性颤振模型对舵系统的颤振特性进行数值计算与分析,计算结果与文献仿真数据较为吻合,验证了模型的有效性。利用该模型计算和分析频率比、重心、扭转刚度等线性参数对舵系统颤振的影响规律。此外,结合两自由度二元水翼任意运动时域水动力计算方法,对舵系统非线性颤振现象进行计算,获取传动间隙等因素对非线性颤振的影响规律。研究结果表明:减小质心到弹性轴的距离、增加舵的扭转刚度,有利于提高颤振速度;间隙等非线性因素的存在可能导致系统出现极限循环振荡,激发噪声,应加以控制。

关键词: 舵系统; 水弹性; 颤振; 间隙; 非线性

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维修工具使用的可达域计算及可视化方法

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摘　要:针对开展虚拟维修时相关仿真软件缺乏维修工具使用时的可达性分析功能之问题,提出一种可达域计算方法以及可达域的三维可视化方法。首先,根据虚拟人手臂结构特点,计算出虚拟人手臂尺寸;在此基础上,结合工具的外沿点位置,给出工具使用时的最远可达距离计算方法;基于该距离值及虚拟人手臂长度值计算可达域几何体放大尺度,利用该尺度可以对工具使用时的可达域进行三维可视化。最后,结合Jack仿真软件,Tcl/Tk以及Python语言,实现了维修工具使用可达性的分析功能。仿真实例表明:所实现的方法能满足工具使用时的可达性分析,所提供的仿真报告自动生成功能有助于仿真人员编制报告。

关键词: 维修工具; 可达性分析; 可达域; 图形可视化; Jack仿真软件