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Ergonomic assessment for DHM simulations facilitated by sensor data

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Abstract

The digital factory with its innovative tools is experiencing an increasing importance, not only in experimental but also productive domains. One of these tools is the digital human model (DHM). In the field of production, the focus of using DHMs lies in the planning and evaluation of processes and products in terms of plausibility, productivity and ergonomics.

Up to now, ergonomic assessment within DHM simulations have been mostly limited to static evaluations of reachability and postures.

INTERACT is a running R&D project, working on the main weak points of DHM software tools. The industry-driven requirements are mainly the reduction of input effort, the increase of movement quality and a quick and intuitive way to create simulation variations in a workshop environment.

The utilization of sensor data to create high quality simulations is another point of development.

Next to the addressed improvement in productivity and plausibility, these latest advancements also enable automatic ergonomic assessments, including process oriented standards like EAWS, OCRA and NIOSH lifting index. The inclusion of these standards will allow a more holistic ergonomic assessment and therewith expand the fields of application in the industrial environment.

This paper will give an insight in the latest developments and the performance of current implementations of automatic ergonomic assessment within digital human models.

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1. Introduction

The interactive nature and the flexibility are the main advantages of digital simulations. Especially in the environment of process planning for manual work tasks, where the classic methods have been using paper boxes as mock-ups and string to plan body postures and walking paths, the advantages of a virtual environment become clear. The creation of process variations within seconds, the exchange of objects in the work place, or the shifting of tasks from one worker to another are just a few of many examples. Next to that software systems possess the ability to measure precisely, when it comes to path lengths, times or joint angles. Thus, the full incorporation of ergonomic assessment methods into DHM software tools may improve evaluation efficiency, objectivity and validity.

Nethertheless, the simulation of manual processes and the ergonomic assessment of these processes hasn’t been used widely in the past. The simulation of manual manufactoring processes has been a very time consuming work, since the definition of body postures and the

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motions in between had to be defined on the level of individual limbs and joints. The massive time effort, which has been needed hindered the digital human model as a technology to become the intuitive and interactive tool it could be. The INTERACT approach tries to focus explicitly on these weaknesses, to raise the digital human model onto a higher level of intuitiveness and interactiveness.

This paper focusses mainly on the ergonomic assessment function of the INTERCAT software prototype. In the following paper the three included assessment methods EAWS, NIOSH lifting index and OCRA will be described, followed by the methodology and the implementation of the regarding software modules.

2. Methodology

The automatic ergonomic assessment with the previously mentioned methods EAWS, NIOSH lifting index and OCRA require a certain amount of information of the process:

- Body postures
- Handled loads
- Forces applied to the body

These parameters have to analyzed discretely, to be able to assign the parameters to each other at every time of the process.

The body posture will be retrieved through the measuring of joint angles and/or distances of joints, limbs and body marks as required by the relevant ergonomic assessment method.

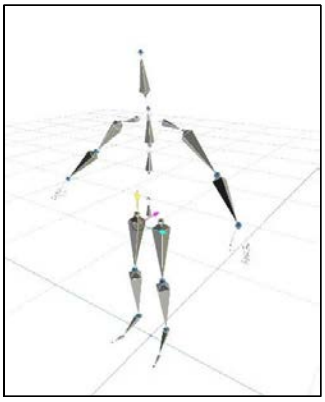

Fig. 1. Skeleton of the INTERACT avatar

The information of the handled loads will be retrieved from the geometry data, which includes information about the mass of the used geometry. If a load in the scene is handled will be retrieved from an 'attached'/'detached' information for the right, left or both hands. The forces will be measured and interactively assign to the process through sensor data. This can be done in advance of the simulation or interactively in the work shop environment. Next to that it will be possible to assign forces manually to individual processes.

The three methods also allow to define 'extra-points' for special ergonomic risks like throwback, sitting on hanging surfaces, walking on sticky floors, etc..

3. Ergonomic assessment modules

3.1. EAWS

The Ergonomic Assessment Work Sheet (EAWS) [1] is a widely used method in the German automotive industry. It's based on a holistic analysis of the work process, considering all executed work tasks in the context of a whole working day.

EAWS is separated in 5 Modules, which are assessed separately. The first module is related to body postures, which are assessed as static (duration > 4 sec.) or dynamic (freq. > 2/min.). A posture is only assessed, if during its occurrence no significant force (> 40 N) or load (>3 Kg) is applied to the worker. If a relevant force or load is occurring, the related parts of the process are assessed with the regarding modules. The first module addresses the extra points, which can't be or at least not easily quantified within a 'standard' assessment. The last module is related to upper limb movements at high frequencies. This module results in an extra index, which is displayed separately. Due to its complex nature and focus on relatively difficult to observe body parts, such as the wrist, this module isn't used widely.

3.2. NIOSH lifting index

The NIOSH lifting index (LI) is a standard assessment method for load handling and together with OCRA one of three ergonomic assessment tools, which are part of the ISO 11228 standard and therewith international standards [2]. The LI applies for lifting and lowering without considering any walking respectively carrying in between.

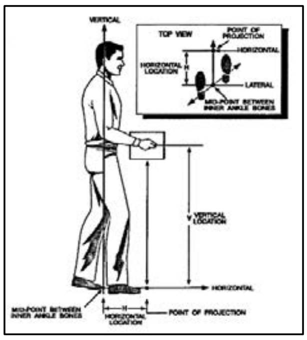

Fig. 2. Graphic representation of hand location

The result of the assessment – the lifting index- displays the quotient between the handled load and a recommended load for the reviewed tasks. The recommended is calculated by the following equation, which combines the parameters weight of the handled object, horizontal (HM) & vertical locations (VM), distance (DM), angle of symmetry (AM), frequency of lift (FM), duration and the coupling (CM) between hands and object:

$$\boxed{RWL} = \boxed{LC} \times \boxed{HM} \times \boxed{VM} \times \boxed{DM} \times \boxed{AM} \times \boxed{FM} \times \boxed{CM}$$

Fig. 3. Equation to calculate the recommended weight for the NIOSH lifting index

3.3. OCRA

The OCRA system is a set of set of tools enabling different levels of risk assessment based on the desired specificity, variability and objectives [3]. As mentioned above its part of ISO 11228. OCRA consists of three modules: the Ocra Mini-Checklist, the Ocra Checklist and the Ocra Index. For an automatic assessment the Ocra Index is the one that is used, because only the Index is developed to quantify the work related exposure and risks on a detailed level.

As the NIOSH lifting index, the OCRA index is a quotient of actual technical actions (ATA) to recommended technical actions (RTA). The definition of technical actions is shown below (see Fig. 4)

Technical action	Criteria
Grasp/Take	Basic rule: 1 TA for grasping of an object with hand or fingers in order to carry out an activity or task. Synonyms: take, hold, grip, grip again, take again, etc. Exception: 0 TA if grasping with contact grip
Grasp with one hand **Grasp with other hand**	The action of passing an object from hand to hand is considered two separate technical actions: - one TA for the right hand (grasp with one hand); - the other TA for the left (grasp with other hand).
Position	Basic rule: 1 TA for positioning an object or tool at a pre-established point. Synonyms: position, lean, put, arrange, put down; equally, re-position, put back, etc.
Putting in; Pulling out	Only when use of force required. Synonyms: to insert, to extract.
Push/Pull	1 considered TA because of need to apply force (even if only little) in order to obtain as specific result. Synonyms: to tear, to press
Release, Let go	Considered TA except where, once object is no longer necessary, it is simply "released" by opening the hand or the fingers.
Start-up	Start-up of a tool requires the use of a push-button or lever by party of the hand, or by one ore more fingers. If start-up done repeatedly, count one technical action for every start-up. Synonyms: press button, lift/lower lever.

Fig. 4. Technical actions in OCRA

Both are calculated by a number of multipliers containing the number of repetitive tasks per shift, Force exertion, posture, recovery and the additional multiplier.

$$\text{OCRA Index} = \frac{\text{overall number of ATA in the shift}}{\text{the number of RTA in the shift}} = \frac{nATA}{nRTA}$$

4. Results

All assessment tools have been analyzed with regard to the quantification and measurement of their input parameters. The current prototypes of the assessment tools contain only those parameters, which are measurable within the INTERACT prototype's functionality. There is still a number of additional parameters, which have to be put in automatically, since they are not assigned to the process or the geometry yet. Some of these additional parameters are the coupling between hand and object during load handling, temperatures or vibration.

The workflow for the development and implementation of the tools has been the same for all three methods: method analysis and preparation, GUI draft, program flow chart, implementation, validation through test scenario.

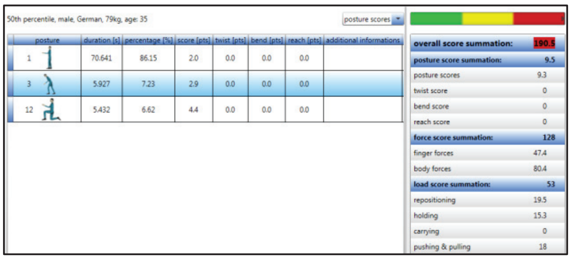

Fig. 5. GUI of the EAWS module

4.1. EAWS

Besides the additional points, EAWS has been transferred to a fully automated assessment tool. The body postures are assessed in every frame of the simulation. The loads are retrieved from the masses, which are assigned to the handled geometry, while forces are assigned to tasks via sensor data in the workshop. The results are displayed through the INTERACT GUI (see Fig. 4). On the right the overall score is displayed, with the distribution of points into the several assessment modules posture, action forces, load handling and extra points. The EAWS result is ranked in the three categories green (0-25 pts.), yellow (25-50 pts.) and red (>50 pts.), which indicates either low risk, intermediate risk or urgent need for adaption of the working conditions. In the left part of the GUI several detailed representations of the individual modules (posture, forces, loads) can be displayed regarding to the requirements of the user.

4.2. NIOSH lifting index

The NIOSH lifting index can be processed almost fully automatically, beside the coupling multiplier between hands and objects. In the long-term, this parameter can be assign directly to the geometry as meta-information. With this further improvement, the NIOSH lifting index will be available as automatic assessment tool.

It has to be mentioned that the NIOSH lifting index shows several weaknesses, as a holistic assessment tools, since it only assesses lifting and lowering tasks and points out a number of restrictions. For example a switch of hands, sitting down, tool handling and other tasks are not allowed to be assessed.

4.3. OCRA

The OCRA method is suitable for an automatic assessment in principle, but there are several challenges coming with it. Not every technical action is defined irrevocably defined, what makes it difficult to determine them explicitly. For the identification of 'putting in/pulling out' it is necessary to be able to differentiate them from a simple 'moving'. For the technical action 'start-up' the software has to know, if a tool is manual or automatic and if it required the pressing of a start-button or not. There are concepts for these problems to be solved, since most the required information can be assigned either to objects or to processes in the future, but the current INTERACT prototype won't allow to implement all of the required features. Nethertheless there is a tool ready for a semi-automatic OCRA assessment, which requires some manual input (see Fig. 6.).

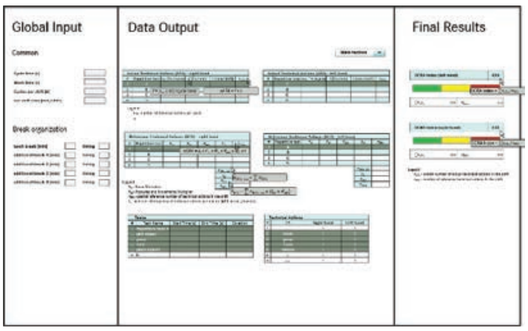

Fig. 6. GUI draft for the OCRA assessment tool

5. Conclusion and discussion

With the automatic assessment with the three process oriented ergonomic assessment tools EAWS, NIOSH lifting index and OCRA, INTERACT makes a big contribution to promote the work with digital human models for the ergonomic evaluation of processes in manufacturing. While all methods show the ability to be used automatically in a virtual environment, there are still problems to solve. Some parameters, which are required by the methods aren't part of the current virtual representations of product and processes. Properties like surface conditions, temperatures or vibrations aren't assigned to virtual objects yet. The INTERACT project strengthens the idea, that the focused goals of higher efficiency, objectivity and validity in ergonomic assessment can be achieved with digital human modelling in the near future.

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[2] ISO 11228-1:2007
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