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Integration of time as a factor in ergonomic simulation

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Abstract. The paper describes the application of a simulation based ergonomic evaluation. Within a pilot project, the algorithms of the screening method of the European Assembly Worksheet were transferred into an existing digital human model. Movement data was recorded with an especially developed hybrid Motion Capturing system. A prototype of the system was built and is currently being tested at the Volkswagen Group. First results showed the feasibility of the simulation based ergonomic evaluation with Motion Capturing.

Keywords: EAWS, Simulation, Motion Capturing

1. Introduction

The Volkswagen Group is facing a big challenge due to a proceeding globalization of markets and an increasing competition. Decreasing product life cycles, the need of flexible production systems and the demographic change demand solutions to assure or rather expand the own competitiveness. Processes have to be created, which assure and support increasing demands concerning productivity and quality as well as ergonomics. In this case, an important aspect is the establishment of ergonomic design methods in the product life cycle. Thus it is possible to influence products and processes as soon as possible in order to reduce costs. However, ergonomic evaluations in phase of development and planning are often difficult. The huge amount of different process simulation tools and digital human models constrain a standardized examination of ergonomics. Furthermore, existing systems do not provide the possibility to include the intensity as well as the duration of exposure for the calculation of an ergonomic index [1]. Only the intensity of physical exposure has been considered with static methods like RULA, OWAS or NIOSH [5, 10]. Therefore, within a pilot project, the algorithms of the method EAWS were transferred into an existing digital human model.

2. Method

2.1. The screening method EAWS

Since 2009, the EAWS, also called European Assembly Worksheet, is the standard ergonomic evaluation method of the Volkswagen Group. Based on some different precursor methods like OWAS, DesignCheck, NPW or AAWS, it was developed between 2006 and 2008 by the International MTM Directorate and the Institute of Ergonomics of the Darmstadt University of Technology [7, 8]. EAWS is a combination of different methods containing an overall view to physical exposure in relation to the duration of its appearance. Therefore, EAWS is a screening method for the ergonomic evaluation of movements instead of single postures. It is divided into the two Macro-Sections “Whole body” and “Upper limbs”. The Macro-Section “Whole body” consists of the three parts “posture”, “action forces” and “manual material handling”. The result of each Macro-Section is a score exposed in a traffic light scheme with green, yellow and red according to the European Machinery Directive 2006/42/EC [4]. The part “posture” considers intensity and time of relevant selected postures like standing, sitting and kneeling [5]. Also trunk flexion, lateral bending, ro-

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tation and position of the hand in relation to the trunk are considered.

The part "action forces" is divided into the load onto fingers and the load onto hand-arm-shoulder-system. In both cases, the intensity score has to be calculated depending on the relation between the real force and the maximal force F_{max}, which is possible to apply from the person. The value of F_{max} can be taken from the document "Force Atlas" [6]. EAWS also considers duration or number of repetitions of applied forces.

The part "Manual materials handling" is divided into "repositioning", "carrying", "holding" and "pushing or pulling". The intensity score is calculated by considering the load weight and posture. Again, the time is considered in form of the duration, the distance or the number of repetitions.

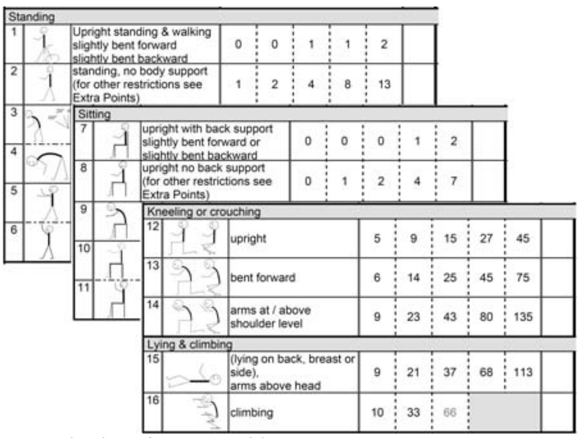

Fig. 1: Evaluation of postures with EAWS [4]

2.2. The Simulation System

The algorithms of EAWS were transferred into the digital human model alaska/Dynamicus [3], which is an application of the multibody simulation tool alaska [2]. Alaska/Dynamicus is mainly used in the field of biomechanics, sports science [12], rehabilitation and also ergonomics. To simulate the posture or movement of the digital human model, data from a Motion Capturing system can be used. The transformation of the Motion Capturing data into an equivalent motion of the human model is performed by an inverse kinematics algorithm. After that, the EAWS score is calculated by considering the intensity and duration of physical exposure. The score of the EAWS part "posture" is automatically generated from the movement. The scores of the parts "action forces" and "manual materials handling" are generated from information which must be entered manually.

2.3. The Motion Capturing System

The advantage of optical motion capturing systems is the very precise data about the position of the sensors. However, regarding the conditions at a workplace in an automotive assembly line, an optical tracking system is not sufficient because of the lack of visibility of the sensors. Thus, the movement data was recorded with a hybrid approach, consisting of an optical tracking system in combination with an inertial tracking system. The redundant information of the inertial system is only used in case of invisibility of the optical system. For optical tracking, a system of the Advanced Realtime Tracking GmbH (A.R.T.) was used. The cameras of the series ARTtrack3 record with a resolution of 640*480 pixels and a sampling rate of 60 Hz. The retro-reflective markers were partially accumulated to rigid bodies, which are called targets (Fig. 2). Each target can be automatically identified by the unique order of its marker positions. For the application described in this paper, targets for the body segments head, breast, pelvis and the left and right side in each case of the following segments were used: shoulder, upper arm, forearm, hand, thigh, shank and foot.

Additionally, the inertial FAB system of Biosyn was used (Fig. 2). It is a combination of accelerometers, gyros and earth's magnetic field sensors. Data is collected at 100 Hz sampling rate and is transmitted wirelessly to a small receiver system with PC connection. The transmission range is 20 meter. The sensors were positioned at the same body segments like the targets of the optical systems, except for shoulder and foot.

3. Prototype for Ergonomic Assessment

The establishment of the Continuous Improvement Process in the production system of the Volkswagen Group is an important aspect. Already in the early stages of development and planning, the whole production process of the assembly is simulated by using 1:1 models. To integrate the human factor in these simulations, the technology of Motion Capturing has the possibility to record the real production process with the purpose of an automatic ergonomic evaluation [1]. The result gives information about potential to improve ergonomic physical workload.

The prototype of the system was built and is being tested at the Volkswagen Group. The application focuses on planning workshops to improve manual assembly operations ergonomically within the Continuous Improvement Process. First measurements were performed at the assembly of battery and wheel arch panel [9]. The feasibility of ergonomic evaluation with Motion Capturing was demonstrated. Also the problem with the lack of visibility of optical sensors in real environments was illustrated. Further tests inside the car body showed the applicability of the hybrid Motion Capturing system with optical and inertial sensors [11]. The example shown in Fig. 2 is the assembly of the restraint system by using an electric screwdriver. All measurements were varied to identify the process with the best ergonomic characteristics. Therefore, the simulation gives the possibility to compare variants of assembly operations. Fig. 3 shows two variants of the assembly of the roof rails. The calculated ergonomic scores differ more than 50 percent.
The implementation of the EAWS method in alaska/Dynamicus is being validated at the moment. Thus, 67 different assembly operations have already been recorded. The next step will be the comparison of the data with the manual paper and pencil evaluation of EAWS.

Fig. 2: Example of an assembly operation with Hybrid Motion Capturing with optical targets and inertial sensors

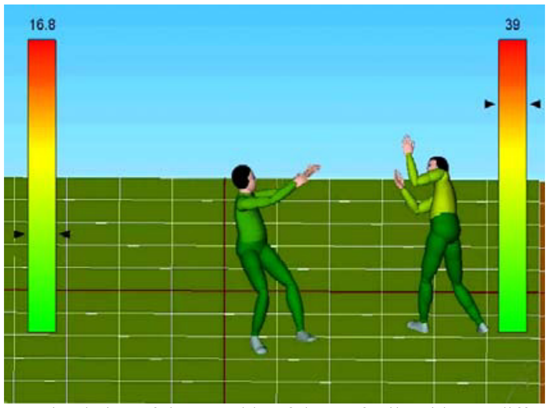

Fig. 3: Simulation of the assenbly of the roof rails with two different variants and EAWS scores

4. Discussion

The integration of the method EAWS was the first approach to consider time as a factor in ergonomic simulation. The simulation based ergonomic evaluation of EAWS is a powerful tool, which is usable for planning workshops with ergonomic interest. In accordance to other authors [10] it was noticed, that performing a simulation with Motion Capturing requires less time than a manual screening. The simulation needs around the triple of process time, whereas a manual screening needs up to 1 hour. Also, the simulation described in this paper needs less time than other software tools using the EAWS method. For example, the time needed for ergonomic evaluation with the device MTMergonomics® is about 240 times higher than the process time, because of the huge amount of manual inputs [13]. Moreover, MTMergonomics® has only the possibility to perform a simplified visualisation of the process, not the real movement. The evaluation data of the simulation described in this paper is repeatable and independent of the person performing the evaluation. On the other hand, the evaluation data depends on the movement and anthropometry of the captured person. Therefore, standardized process descriptions, standardized qualifications and a correct interpretation in case of different anthropometrics are necessary to get a valid result.

The hybrid Motion Capturing technology passed the test measurements in the real environments. The accuracy of measurement data has increased significantly by using the combination of optical and inertial systems [11].

5. Conclusion

A prototype for a simulation based ergonomic evaluation using the method EAWS has been developed and tested successfully. First measurements demonstrated the advantages of the system in terms of evaluation time, repeatability and objectiveness. Furthermore, the hybrid Motion Capturing technology was proved to be a useful device for recording real postures and movements. Current tasks comprise the validation of the implementation of the EAWS method in the digital human model.

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