Application and Future Developments of EMA in Digital Production Planning and Ergonomics

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Abstract. The Editor for Manual Work Activities (EMA), a planning method based on a 3D digital human model, addresses the need for realistic and holistic assessment of time and ergonomics in an early phase of product, process and resource planning. Since the first introduction of EMA in 2011 practical applications have triggered several improvements driven by the requirements of various industrial customers. Experiences in different branches called for a wide focus of new developments that now allow a broader application. This paper illustrates the connection between practical requirements and technical improvements of EMA within the past years. It also demonstrates how EMA may contribute to cost-efficient and accurate planning in different phases of the product development cycle. Finally, some of the future developments are illustrated.

Keywords: Digital Human Modeling, Production Planning, Ergonomics.

1 Introduction

Demographic change is one of the widely used keywords for reasoning investments on the field of ergonomics. Fact is that the ageing of the workforce – mostly caused by extended life expectation and decreasing fertility – has become a major productivity risk, especially in manual assembly tasks. Causing already almost one third of all sick leaves, musculoskeletal disorders (MSD) show a significant higher prevalence at a higher age [1][2]. The urgency for ergonomic countermeasures increases thusly.

It is well known that the later these countermeasures are taken, the less impact they have and the more it will cost. Therefore cost-efficiency will be highest in early phases of production planning [3][4]. Once series production has started costs of changes may easily outnumber the benefits retrieved from improvement of ergonomics. As a consequence, production planners have a high responsibility not only to assure good ergonomics, but also other aspects of "good work" such as efficiency and feasibility. In order to meet these objectives appropriate methods for digital production planning are needed. Simulating the interaction between products (car body, part etc.), work processes (assembly tasks) and equipment (tools, machinery) with human resources is a promising holistic approach for validation and evaluation purposes in early planning phases. Yet, simulation methods themselves

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need to be efficient and intuitively applicable in order to conduct digital evaluations in a timely manner.

In regard to preventive ergonomic work design during pre-production planning, digital human models (DHM) have been considered a very promising method [5], however most DHM suffer from a time-consuming simulation and inefficient adaption and variation with regard to illustrating design alternatives. The reasons are manifold, but they can often be found in static posture generation through inverse kinematics. Especially when it comes to dynamic simulation and human motion generation conventional methods lack precision, validity and variability.

This paper introduces EMA (Editor for Manual Work Activities), a software-based planning method that resolves most deficiencies of current DHM tools. Main focus of this paper is to present practical applications of EMA and to give an outlook on future developments.

2 Rediscovering EMA

2.1 The Definition of EMA

In 2011 EMA was introduced by Fritzsche et al. as a software tool "[…] that reduces the effort for preparing simulations of human work and, at the same time, improves the accuracy of simulations" [6]. Through practical application and continuous improvement in the past years it has become more than a software tool – it is now considered as a software-based planning method, which uses 3D-DHM simulations and established "process languages". This method allows a holistic and realistic assessment of human work in regard to time efficiency, feasibility and ergonomics through the fast and variable simulation of human motion.

There are several advantages that distinguish EMA from other planning methods / DHM application tools:

- Easy to use by drag and drop handling metaphors
- Use of typical planning language suitable for manufacturing applications ("pick part A, place in appliance B, use tool C to fixate")
- Self-initiated motion generation
- Use of object references
- MTM-based standard-time calculation
- EAWS-based ergonomic assessment of full-shift physical strain

EMA's key to efficient human motion simulation is the continuous use of object references and the self-initiated motion generation, which is based on motion-capturing studies with real production worker. Once the task is described in very simple language ("pick part A, place …") and specified by certain parameters (which part and location etc.), EMA will generate human motion without further ado, thus being fast and realistic. Using relative object references EMA will always find the specified object, no matter how often it has been moved in the 3D-environment. This enables the user to generate alternative design and planning scenarios in a very short time just by moving the referenced object to another location or by changing certain object preferences, such as shape, size, or weight. Unlike other DHM nothing else within the simulation needs to be adapted to create such an alternative scenario. Multiple planning solutions can be tested in a cost-efficient way by using this method for a fast variation of processes (order of tasks etc.), products (weight and dimensions etc.) and resources (5^{th}%ile vs. 95^{th}%ile etc.)[7]. Moreover, the most relevant planning objectives – production time, physical workload and geometric feasibility – can be evaluated and objectively compared based on the produced reports on standard assessment methods (MTM-time and EAWS-ergonomics).

For ergonomic risk assessment the EAWS (Ergonomic Assessment Worksheet [8]) has been implemented. It is the only commonly used holistic method that allows the evaluation of physical workload throughout the entire work process. Additional analysis functions of EMA can be used to avoid waste (in reference to the Toyota Production System); for instance, by illustrating ergonomic strains, long walking distances, and double handling of parts and tools.

In summary, these EMA report tools enable the production planner to compare alternatives of product and process design by means of objective quantitative analyses of efficiency and ergonomics based on human simulations.

2.2 From Software Implementation to Stand-Alone-Software

When EMA was first introduced in 2011 it was only available as a plug-in for Dassault Systèmes' Delmia V5 software suite that is now called "EMA-V5". In the meantime, EMA is also available as a stand-alone system that could be incorporated in nearly all PLM/PDM systems. It offers the same scope of services but appears as a more flexible and lean system with more data interfaces and modular expandability. The figure below shows the new EMA interface.

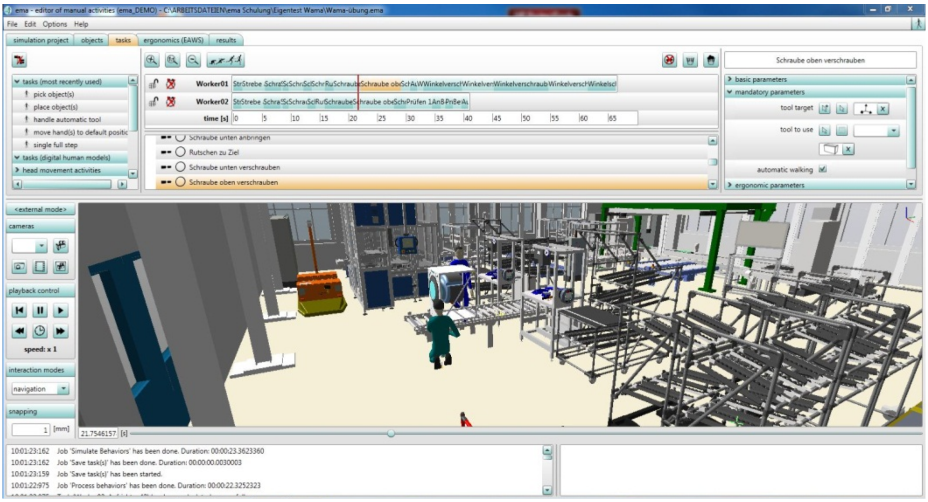

Fig. 1. EMA user interface

The main difference between EMA as a standalone software and EMA-V5 is the integrated 3D graphic engine and the advanced human model. EMA-V5 still offers the same user interface and functions, but shows the simulation in the DELMIA window using the “Delmia Human Builder” manikin as human model.

This evolution of EMA to a stand-alone-software widens the area of application because it allows an even more customer-specific adaption of the software and better usability. Especially SMEs should be interested in using a lean system without having to purchase a costly full PLM-system, yet still have the same benefits. Generally, EMA is a very flexible system that allows companies to incorporate the software in their own specific IT-landscape. In the past several company-specific methods were integrated, such as an individual ergonomic assessment tool of a large automotive OEM.

Since 2011 the performance and efficiency of EMA has increased significantly. By now, simulations can be generated using less complex operations and thus, in a much quicker manner. For example, EMA is now able to automatically calculate the shortest walkway and the best relative position for picking and placing objects.

Also the validation of human motion through motion-capturing was continued, thus creating even more realistic human motion in regard to execution and duration. Both of these factors are very important for increasing the accuracy of ergonomic assessment and time prediction. Field studies that were conducted at VOLKSWAGEN, one of the most prominent EMA users, compared ergonomic assessments with EAWS in paper-pencil and EMA demonstrating significant correlations between the conventional scores and the results calculated with EMA [9]. Internal studies about MTM-1 analysis and EMA production time have shown deviations of less than 5 %, thus being sufficiently accurate for planning purposes.

In order to increase the timely accuracy of EMA and ensure a full translation of EMA process languages into MTM-codes, the EMA-family will grow by a full integration in MTM’s standard software system for time analysis called “TiCon”. As a long-term result EMA will be able to generate MTM-codes out of the simulation and vice-versa [10].

3 Practical Application of EMA

The industrial application of EMA has been a key element to further improvement of the planning method and the DHM. Especially the wide range of industries and tasks has offered significant inputs for improving motion generation, software usability and analysis functions. Most partners are OEM’s in automotive industry, like Audi, BMW, Daimler and Volkswagen. However especially applications in other industries, such as aviation industry (Airbus), textile machinery (Karl Mayer Textilmaschinenfabrik) and white goods, ensure a broad development of EMA driven by the very diverse requirements of each industry.

The following paragraphs specify areas of application in the product development cycle and illustrate three examples of EMA application describing their contribution to further development.

3.1 Areas of Application

EMA can and certainly should be used during the entire product development process. The earlier EMA is used in product conception and production planning, the more costs for re-design can be saved; however, EMA can be applied in all phases, from concept design, to pre-production planning, pre-series production trails and series production.

During the concept phase the focus is certainly put on buildability and plausibility checks. Ergonomics and time can only be assessed rudimentarily due to the lack of process descriptions, but the simulation and analysis functions offer an early estimation of bottle-neck-processes in regard to physical workload and manufacturing time. These early assessments have a strong product-reference; however they should also be used to evaluate concepts for facilities, equipment, and production layout in general.

The definition of standard working sequences should be the result of pre-production planning. The planning method EMA can be used for compilation and validation of optimal work processes and product specification, while various alternatives are assessed and visualized within the 3D environment. This phase has a strong process focus and lays the foundation for the following pre-series planning. The ergonomic assessment and time analysis now requires greater detail and, for the first time in the product development cycle, focuses on the whole cycle or shift.

Pre-series production offers a last chance to optimize product, process and resource before series production starts. This requires simulations and analysis to be very detailed and accurate. If the simulation with EMA has been gradually build up throughout the product development process only minor adjustments need to be made and last changes can be virtually assessed without expensive tryouts. Similarly EMA could be used to support the continuous improvement process during series production. Hereby mostly the integration of new concepts in regard to product, process and resource is of importance. Again, a simulation and analysis with EMA avoids the interruption of the production process for costly try-outs. In that phase EMA may also be used for qualification matters. The simulation videos illustrate standard working procedures that newly hired workers need to learn before they can be deployed at the running production line. In that sense, EMA may also serve to support communication between planning and production because it shows the ideal process just as it was intended to run.

After start of production, EMA is particularly useful to investigate layout optimization and the integration of new tools or machinery in running production lines, before they actually exist. Within the 3D environment the available space of the workplace becomes visible and illustrates the future work process without physical tryouts or interruptions of the running production.

3.2 Industrial Application I

An early scenario of EMA application consisted of multiple picking tasks in the logistics supermarket area for an automobile assembly line (Fig. 2). At first, EMA had several problems simulating material handling tasks. For example, until that date it was not possible to operate multiple parts. Therefore the whole operation of material handling needed to be remodeled, so several parts could be grabbed and released by the DHM at different times. Furthermore the operation for pushing and pulling trolleys and carts needed to be implemented. More structural elements for subcategorizing tasks needed to be created for a correct ergonomic assessment with EAWS (pushing includes grabbing, connecting, walking and releasing). The implementation of another structural level however also helped organizing the tasks into operation sequences, which are often used in larger companies as structural elements within their PLM-system. Therefore EMA could now also inherit the structure of tasks used in most companies. For instance, the tasks “pick up lid”, “walk to car body” and “place lid in appliance” can now be merged in the operation sequence “install front lid”.

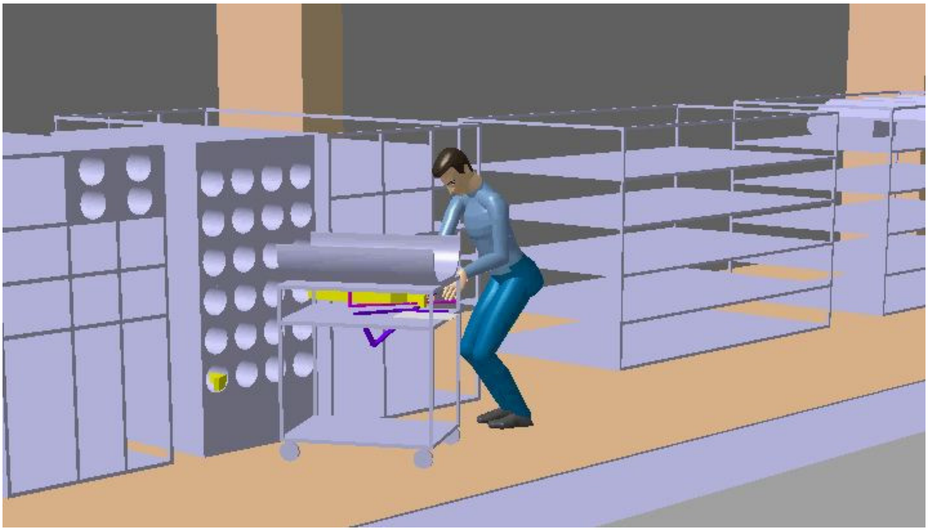

Fig. 2. Pushing and pulling during consignment tasks in EMA V5

Another focus of this application was the mapping of EMA standard time with MTM-time. Before, the deviations of the time simulated by EMA and MTM-1-time were significant for certain tasks and movements. Based on this example, however, the timely accuracy of EMA was tremendously increased by conducting a step-by-step comparison of movements and MTM-1 modules.

3.3 Industrial Application II

Another very interesting application at a textile machinery plant (Karl Mayer Textilmaschinenfabrik) showed that EMA can be used in a wide range of areas. The main focus was design improvement in regard to maintenance tasks. These can be

Fig. 3. Different possible postures of EMA

very time-consuming due to large machinery and odd postures and movements that need to be executed in order to reach certain maintenance accesses. Such movements consist of crawling, kneeling, sliding and lying as well as motions to and from these postures. In this example, EMA was used in order to get an accurate estimation of accessibility and time need for certain maintenance tasks, (Fig. 3). Besides that, also typical applications in manual assembly tasks, especially in the automotive industry, benefit from this specific development: In-car motion such as sliding from one side to another can now be simulated and assigned with a standard planning time based on MTM-1.

3.4 Industrial Application III

Tool handling has been another big issue during the development of EMA. In order to be effective and accurate in creating the simulation, tools need to be handled by EMA without further information-input by the planner. Applications at Daimler (Mercedes-Benz Manufacturing Hungary) and Volkswagen (Kaluga plant in Russia) have offered a variety of scenarios to use specific tools. Particularly, the use of welding tongs and different pistol-grip tools have shown the most important determinants for tool handling. Firstly a tool-center point (TCP) needed to be defined, which describes the place and orientation of the application point. Secondly each tool needed a special gripping point to ensure correct hand-wrist-orientation. Thirdly, specific body movements had to be created depending on the tool trajectory; EMA nowadays automatically follows the tool step by step and always finds the optimal posture in reference to the place of application (Fig. 4). In the near future the tool-objects will inherit more information about the process, such as involved body forces and necessary movements. This way, manual and automatic tools will automatically cause a different execution of a task.

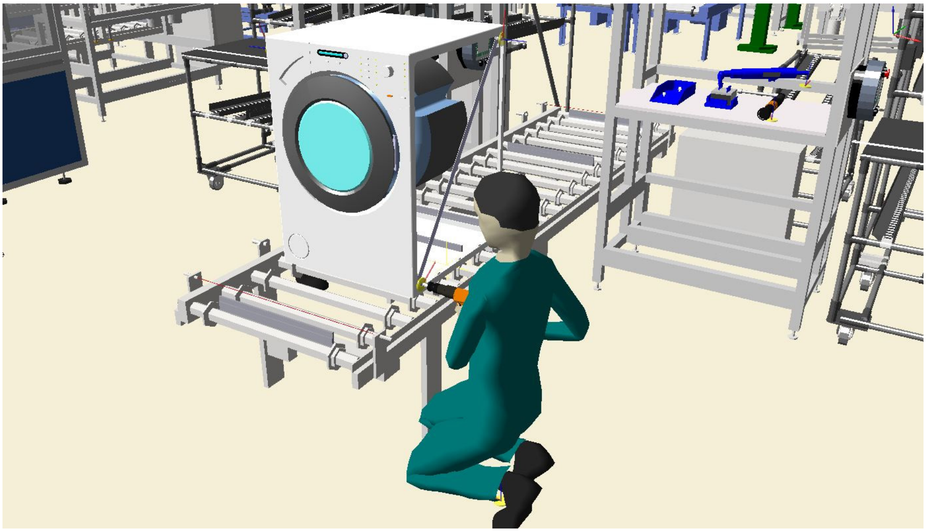

Fig. 4. Tool-based positioning of EMA (white goods example)

4 Future Developments

Triggered by the continuous input and requirements of customers as well as general trends within the industry, the future development of EMA will ensure that the planning process with EMA constantly improves in efficiency and accuracy. Currently the possible extensions seem endless; however some are certainly of more concern. The most important ones that are going to be implemented in the near future are presented in the following.

Currently object constraints can only be realized within the 3D-Layout, since creating constraints during tasks of the DHM is especially challenging. This is necessary if an object needs to be assembled and then handled again as a single object. However this feature will be implemented shortly. A related topic is working in and on moving objects, which exists quite often especially in assembly lines. No currently available DHM or production planning systems allows this kind of simulation, yet the consequent use of object reference in EMA creates the ability to always find its objects within the 3D environment, thus allowing working in and on place-unsteady objects.

Another constant subject of further development is the reduction of user commands. More automatic algorithms for situation-based motion generation are required to reduce the number of user interactions and finally, increase the efficiency of EMA simulations. One example is the context-based walking target selection, which eliminates the need to specify walking patterns, thus reducing the number of commands needed. Walking targets may differ in reference to the geometry of objects that are picked and placed.

Another key to reduced commands is a detailed collision control. Currently, collision control is implemented only for lower extremities. The more the DHM automatically generates correct human motion, the fewer tasks need to be specified. The long-term objective is a full collision control, which will be implemented gradually. At the moment, a major drawback of full collision control is that system performance is strongly impeded. Despite being a very lean system, EMA constantly needs performance optimization in order to realize such computationally intensive operations. Shape-based parameterizations are closely related to collision control. Behind this bulky expression one can find features like automatic grip-point definition at complex objects. EMA will then always find the optimal grip-point, for example the handle of a can.

Beside the improvement of the simulation in terms of efficiency and accuracy, also the analysis functions will be enhanced. For example, the so-called Ergo-Optimizer will not only allow an assessment of risks, but also aid the planner to systematically reduce ergonomic risks by taking the most effectives countermeasures in a certain situation.

One last development is the further extension of PLM-system-interfaces. Currently Collada and JT are defined as standard data-formats, but in addition to improving JT-data handling a new set of extensions and applications may be accessible with advanced data-handling procedures. Future applications may range from automatic data import from construction data management systems to a full implementation of (company-specific) library data elements (tools, anthropometry data, standard racks etc.).

5 Conclusions

In the past years EMA has evolved from a planning tool that uses an innovative approach for human motion generation to a full grown planning method. This paper has shown that industrial applications have greatly contributed to the improvement of movement-accuracy and planning-efficiency. A main focus was put on motion generation as the core competence, however also the performance of different assessment methods, such as EAWS for ergonomic assessment and MTM for time analysis, greatly benefited from the requirements that were defined by EMA customers. Through the use of EMA in the automotive industry, aviation industry, white goods and other industries the range of possible tasks and the system performance vastly increased and created many ideas for future developments. Especially in terms of data exchange of the software and interaction with the surrounding 3D-environment of the DHM, EMA will soon allow a broader and more efficient applicability in all phases of the product development process.

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