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Increasing knowledge and skills for assembly processes through interactive 3D-PDFs

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Abstract

Extending PDFs with interactive three-dimensional CAD content is an opportunity to enable users with different knowledge levels to understand assembly processes. Users are enabled to manipulate CAD content by a combination of pictograms and text, without any knowledge on how to handle CAD programs. A generic structure for an interactive 3D-PDF, containing manual assembly tasks, has been developed as a so-called learnstrument. Visual, haptic and aurally learning methods are integrated in 3D-PDFs to facilitate sustainable development worldwide.

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1. Introduction

To cope with rising market demands and innovative competitors, globally acting manufacturing companies need a possibility to share knowledge about assembly processes in a way, which is quickly and easily comprehensible for assembly workers. The demand to qualify workers is especially high for companies in the special machinery segment, as they need highly educated and skilled workforces for their specialized one of a kind production.

Two contradictions have to be addressed while discussing the distribution of knowledge. The knowledge sharing process has to be on one hand safe, to make it more difficult for competitors to access the knowledge. On the other hand, the process needs to be easy to access, fast and comfortable for users to motivate people to spread and use knowledge through simple processes. Challenges of different knowledge levels, cultural backgrounds, languages, age and learning styles of users have to be addressed to enable various users to understand instructions fast and correct.

Assembly workers in the special machinery segment already have the essential abilities to assemble complex products naturally or they have gained them through apprenticeship.

These abilities are a prerequisite to develop and improve their skills for specific assembly purposes and products through training. They additionally have to extend their knowledge about new and improved products and working methods through education.

Skills can be divided into cognitive, technical and interpersonal skills. This paper focuses on the improvement of technical skills. The technical skill level of assembly workers can be segregated into five categories: novice, competent, proficient, expert and master [1].

After finishing his apprenticeship, a novice is typically educated by an experienced worker, while working together with him. This process is well-practiced in most companies but has certain deficits:

- Two workers are involved in the teaching-learning process, which doubles the knowledge transfer cost,
- each novice gains different knowledge from his expert,
- best practice assembly methods are not spread and
- only one expert is able to teach the best-known method for a task to a novice. All other experts teach methods that are more inefficient.

Beside the knowledge transfer from expert to novice, there are three other cases to be discussed in the field of special machinery:

- New assembly workers of all skill levels have to be educated about unfamiliar products and processes,
- skills and knowledge of workers have not only to be improved in one plant but in multiple locations worldwide which are assembling similar products and
- if the company has a service department, assembly workers from different locations need training and education for in field service assembly operations.

Sharing assembly knowledge between different plants of one company and building a global knowledge network would be beneficial for improving assembly knowledge worldwide. In some cases workers, especially when working in high-wage countries, fear to lose their jobs when they allow others to access their knowledge. They fear a distribution of their work to other locations with lower wages. Therefore, the sharing of assembly knowledge has to be carried out in a way that does not only concerns the interests of the company but especially addresses the interests of the workers, who are the knowledge holders.

While transferring knowledge between countries with different languages, a translation of the written content is necessary. The higher the amount of words and the number of translated languages, the higher the translation costs and the potential for translation errors. Translation errors are especially problematic if signal words are translated wrong in their context. According to DIN EN 15038 [2] and its internationalized version ISO 17100 [3] the four-eye principle is used to check translations. Both norms show the possibility of supplementary quality checks of translations but give no suggestion about when they have to be applied. Additional quality checks are cost intensive and time consuming. Therefore, they are not carried out in most cases, which hinders finding translation errors for instructions with higher risk potential. Furthermore reducing the written content has a big cost saving potential the higher the more languages are needed. It is also time consuming to read long texts and it can be difficult to understand these texts, because how easy understandable a text is depends on the author's linguistic competences.

2. State of the art

2.1. Learnstruments

“Learnstruments are artefacts and systems which automatically mediate their functioning to their user” [4]. One aim of learnstruments is to increase teaching and learning activities through their simple usage. Therefore, learning and working environments are combined and learning methods and tools are selected and applied in industrial artefacts. Learnstruments can be used to improve the efficiency of manual assembly processes. Human motion capture technology is used to analyze the assembly motions of a worker at an assembly table, while enabling ergonomic working in a first example for a learnstrument [5]. By “help of a so called qualification module, intuitive work descriptions can be

generated and distributed. The qualification module consists of a combined pose-recognition [and] learning module for assembly sequence definition and control” [6].

Another example of a learnstrument is an interactive graphical visualization of sustainable manufacturing aspects of a bicycle assembly [7]. This web based product configurator shows a pedelec with a default setting, where standard steel parts are assembled. The user has to decide based on his instinct and the product characteristics which configuration is the most sustainable one. After he submitted his configuration, he gets a feedback how sustainable his solution is. He is now enabled to freely change his setup while the sustainability scores in ecologic, economic and social dimension are displayed. This interactive concept is different from traditional ones. In the internet “various concepts (e.g. Wikis, Glossaries, Tutorials) are applied to represent knowledge[,] each utilizing different sets of media [...], but mostly without interactive elements. In terms of sustainable manufacturing such static representations are insufficient as an understanding of complex relationships is necessary” [7].

2.2. Multisensory learning

In contrast to unisensory learning in multisensory learning more than one sense is utilized for educational purposes.

One big advantage of multisensory learning or training is that it can “engage individuals with different learning styles, for example, some people are ‘visual learners’ and others ‘auditory learners’. [...] Multisensory training is demonstratively more effective at an individual level” [8]. For example “People generally remember 10% of what they read, 20% of what they hear, 30% of what they see, and 50% of what they see and hear” [9]. Most instructions in the field of special machinery address only one or two learning styles, e.g. written instructions or technical drawings.

Different researches indicate that multimodal processing reduces cognitive load, because information from different modalities can be more easily stored into short-term memory and used to build long-term representations [8, 10].

2.3. International instructions

One basic approach about a generic model for international assembly instructions for special machinery assembly has been implemented at a special machinery company for turbo-compressors in Changzhou, China [6]. By reducing the amount of written text and increasing the number of photos and pictograms in an assembly instruction, an easier understanding of the complex assembly tasks by the Chinese workers was achieved. CAD explosion drawings were used to give an overview of each task. This helped the unexperienced workers to identify new parts as well as their assembly sequence. The design of the whole instruction helped to understand the content without hardly any background knowledge, which was mainly achieved by the increased use of figures. Different knowledge levels of the workers have been addressed in this approach, whereas all workers had the necessary abilities and a certain amount of background knowledge. Novices were not addressed.

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