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Method for design of human-industrial robot collaboration workstations

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Abstract

In order to fully utilise a 3D simulation software capable of evaluating hand-guided human-industrial robot collaborative (HIRC) work tasks, there is a need of a HIRC design process for early production development stages. This paper proposes a HIRC design method that uses the possibilities of the demonstrator software in the HIRC workstation design process. The method is based on Pahl and Beitz's engineering design method; it interprets all their phases and activities into HIRC design-specific ones.

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1. Introduction

Human-industrial robot collaboration (HIRC) is a rapidly growing field in research. A literature search performed in 2015 showed a four-time increase in the number of academic publications per year between 2005 and 2014 [1]. The potential to combine the beneficial characteristics of the human with those of the industrial robot opens huge possibilities to simultaneously increase productivity and reduce ergonomically bad work postures [2]. The vision is

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to create more productive workstations through combining human intelligence and flexibility with industrial robotic strength, endurance and accuracy [3, 4].

Simulation software is used in manufacturing companies early in production development processes to shorten development time, increase quality and reduce costs [5]. These tools are used to support decision making in the companies [6] and are an integral part of the engineering activities in many manufacturing companies [7]. However, this statement is not valid for HIRC systems; the possibility to virtually evaluate entire HIRC systems before making an investment decision is very limited in available simulation software.

In order to meet this need, a demonstrator simulation software was developed, making it possible to design and evaluate HIRC workstation layouts early in the production development phases [8]. This software enables simulation of hand-guiding HIRC tasks in 3D CAD environments. It can be used to analyse reachability for both industrial robots and humans, present layout alternatives and be a tool for risk assessment in HIRC workstation design assignments. The software generates quantitative outputs considering operation time and biomechanical load assessments for fully manual, fully automated and any hybrid (HIRC) workstation. These quantitative outputs can be used to compare alternative solutions in an objective way.

The demonstrator software is designed to be used during HIRC workstation design. However, to get the full potential from virtual simulations, there is a need of a HIRC design process for early production development stages. Thus, the aim of this paper is to propose a HIRC design method that can be used in early phases on production development processes.

2. Method

Experience from design of four industrial HIRC cases [8, 9] in the development of the HIRC demonstrator simulation software led to the development of the proposed method. In order to gain validity of the proposed HIRC design method, it was connected to existing design methods. Pahl and Beitz's engineering design method was chosen, as it has become the reference work to teach design engineers a systematic method to include a heterogeneous set of theories and methods for one product design process [10]. The latest English edition (3rd) of their work (co-authored by Feldheusen and Grote) was used in developing the HIRC design method proposed in this paper [11]. The method is referred to as the engineering design framework in this paper.

3. Frame of reference

Systematic design has been developed over the past several decades as a best practice for product design [12]. A frequent view in design research is to consider the design process as following a sequential scheme. From product planning and design, a number of processes have been proposed that follow that scheme, e.g., [11], [13-15]. These generic design processes have been applied in production development processes, such as [16-19].

The book *Engineering design: a systematic approach* written by Pahl and Beitz was first released in 1977 in German, *Konstruktionslehre* [20]; it has become the reference work in teaching design processes [10]. This engineering design framework consists of four main phases: planning, conceptual design, embodiment design and detailed design [11]. Despite the linear flow from planning to detailed design, it is important to understand that design is an iterative process, demanding use of new knowledge back in previous phases and activities.

HIRC design methods presented in research publications are mainly limited to the work task allocation problem, i.e., which resource is most suitable to perform a task: the human or the industrial robot? Pini el al. also base their design approach in the engineering design framework presented by Pahl and Beitz [21]. They present qualitative suitability comparison between manual and robotic task allocation. Economic profitability of the solution are included. Chen et al. present a method to use multi-objective optimisation techniques to choose a suitable task allocation based on assembly time and economic cost [22]. Tsarouchi et al. have a similar approach in their task allocation method [23]. They present an decision making method that considers mean flowtime and utilisation costs in its decisions. All these methods use time and cost as evaluation criteria, but none of them describes how to gather data into the selection process. One approach is to measure these before the task allocation can begin. However, in early phases of production design it is difficult to achieve these data since no physical workstation exists. This