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A method for planning human robot shared tasks

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ABSTRACT

A multi criteria method, in support of the planning of shared human robot assembly tasks is presented in this paper. CAD models are used for the extraction of a product's assembly sequence, whilst an algorithm is applied for the generation and examination of alternative assignment scenarios. The design algorithm performs the joint planning of task-to-resource assignment and cell layout at the same time. The evaluation of each planning scenario against a set of ergonomics, quality and productivity criteria is made for the identification of the most efficient ones. The method's implementation, in the form of a prototype planning tool (Task Planner), enables its application to a pilot case from the automotive industry. The results indicate that the method can provide high quality solutions with respect to the end users' criteria and has potential applicability as a decision making support tool in the planning stage.

Introduction

Over the last years, the research performed both in the industrial and academic community, has acknowledged the merits of human robot cooperative assembly applications. The synergy effect of the robot's precision, repeatability and strength along with the human intelligence and flexibility [1] provides several advantages, especially in the case of a small-scale production, where leanness, re-configurability and adaptability are of high significance [2,3,4,5]. As a result, new projects [6,7,8] and products [9,10] have been introduced for the exploitation of the flexibility and productivity potential of these hybrid systems, whilst research attempts have been made for their in-depth investigation [11] of the newly arising issues, namely safety [12,13]. Krüger et al. [14] have identified "workplace sharing" and "workplace and time" sharing systems as the main categories for the classification of human robot cooperative cells. In both categories, human operators and robots co-exist within the same space and are capable of performing tasks, either individually or cooperatively [15].

The current industrial deployments strictly separate the working areas of humans and robots in order to ensure the safety of the operators. They are not designed to efficiently accommodate both types of production entities. On the one hand, the design of a robotic cell neglects the ergonomic positioning of components, since the robots are not affected by such strains. On the other hand, a workplace designed for humans fails to meet a stationary robot's reachability constraints, since the operators can move freely within the cell.

Therefore, in order to enable the systematic design and deployment of human-robot task sharing applications, planning tools and methods are required with the ability to simultaneously perform: a) the effective allocation of production tasks to humans and robots, based on their intrinsic characteristics and b) the generation and examination of detailed alternative cell layouts that can efficiently accommodate these task allocations. The latter requires enhanced methods for evaluating the ergonomic impact of the different task assignments [16] and the optimization of the individual activities (e.g. motion and path planning) [17]. The latest human simulation packages already offer several of these functionalities [18].

Up to now, research has been done on multi-criteria planning and the assignment of tasks to production resources, either in automated manufacturing plants [19] or in human based productions systems [20]. Very few authors have addressed the planning of hybrid systems, but it is widely acceptable that through efficient planning, the assembly time and costs can be reduced in any type of system [21]. In this direction, some approaches have provided a quantitative way for the modelling and evaluation of the collaborative tasks [22]. Takata and Hirano [23] discussed a method that focuses on the calculation of production costs, whilst also foreseeing future changes in the production scenarios about the allocation of tasks between humans and robots. The approach however, neglects the layout of the actual cell and adopts a qualitative, user input-based model for determining whether a robot or a human is capable of undertaking a task. The product

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structure and specifications have not been studied in detail. On the other hand, the allocation of tasks to resources, as well as the configuration and layout planning [24,25] of the robotic assembly lines, with the application of intelligent search algorithms have also been thoroughly examined by Michalos et al. [26], Michalos et al. [27] and Michalos et al. [28]. Other decisional architectures have focused on production plans in which the human-robot cooperation is socially acceptable [29].

In Section “Planning of human robot shared tasks” of this study, a multi-criteria method that can assign tasks to humans and robots, while considering the spatial layout of the assembly workplace is presented. The products’ CAD models are used for the extraction of the assembly sequence, whilst an intelligent algorithm is applied for the generation and examination of alternative planning scenarios. Section “Implementation”, describes the method’s implementation in the form of a web-based tool, whilst Section “Case study”, demonstrates its application to an automotive case study. The last section draws conclusions and provides the outlook for future research.

Planning of human robot shared tasks

Problem definition and assumptions

This work aims to address the concurrent layout planning and task assignment problems in case that human operators and industrial robots are able to operate in the same workspace and on the same product. These two problems are complex when it comes to modelling joint tasks and are usually dealt with as individual components of the process planning problem. The following assumptions have been made to allow the definition of a common model:

1. The method is targeted at the early design stage, known as rough planning, which involves activities such as the determination of resources to be used, rough cost estimate generation and rough facility layout determination. Therefore, the exact motion plans of the robots or the detailed actions to be performed by the humans are not addressed. These are part of a detailed planning stage, which also involves the simulation and optimization of the workflow and are being investigated outside of this work. The developed tools are aimed at providing a quick solution to the combined layout and task assignment problem in the case of Human Robot Collaborative cells. The intervention of the human planner is still required in multiple steps of the workflow since the experience and reasoning capabilities of any algorithm are still far from those of humans.

2. The list of all equipment in the cell is given as input. The scope is of this assumption is based on the fact that not all types of existing equipment are available on a single computer and also the fact that the tool should consider the actual available resources at the end user facilities. As an example, a small SME that already possesses some working tables, robots or other fixed machines, should be able to maximize their reutilization in the design of the new cell. On the other hand, this assumption also creates a limitation, because the optimal set of equipment is strongly dependent both on the resource assignment and on the cell layout (e.g., in case of storage devices, whether a human or a robot will pick the part, and how it will be accessed).

3. The scope of the process planning activity is limited to a single workstation, where multiple resources (both humans and robots) can operate. The same procedure can be applied to each individual workstation to arrive at a line level process plan. Another constraint of the method is the fact that it currently uses all of the available resources, defined by the user. This means that the derived solutions will consider all humans and robots during the layout planning, however, without eventually assigning any tasks to them if the selection criteria values indicate so. The development of a selection algorithm to for the derivation of plans with a variable number of resources is an ongoing work.

4. The method considers multiple types of tasks including assembly, picking, loading and any other user defined tasks as long as there are suitable resources defined for this type of a task. With respect to the definition of the tasks to be used in the planning, the method distinguishes the following:

a. Assembly tasks that can be automatically derived by the CAD models via software tools, described in Section “Data input and task extraction from assembly CADs”.
b. User defined tasks (e.g. picking, inspection etc.) that can be inserted directly by the user into an xml format file.

5. The developed method and tool is able to handle and assign tasks to active resources i.e. humans and robots. Nevertheless, other types of resources or equipment that do not perform a task i.e. fixtures, storage locations, stationary equipment etc. may be included in the layout formation process. These resources can be linked to the start/end position of a part (e.g. a shelf may be the starting position for a part) thus, affecting the ergonomy of the workplace. Besides this function, these resources are considered as obstacles to be avoided by the human/robot. The model cannot consider the simultaneous execution of tasks by multiple resources on the same task. This is proposed for future study and is already an ongoing investigation.

6. The method considers that a base part is used and all other components are assembled onto it. The user has to define this part at the beginning of the process, whilst the position of all other items is determined by the proposed method. More details are provided in the following sections.

The proposed method is applicable to several cases where hybrid environments can be perceived to include: shared tasks and workspace, common task and workspace and common tasks in a separate workspace. The common denominator under such applications is the need to automate tasks that are not appropriate for humans due to ergonomy/strain issues or lack of required accuracy/strength. The latest reports indicate that human robot collaborative applications are expected to meet a highly increased demand, favoured by the latest investment in industrial robotics. The four industry groups that are expected to be on the front of investment for robotics are: computers and electronic products; electrical equipment, appliances, and components; transportation equipment; and machinery. At least 85% of the production tasks in these industries are automatable involving assembly and the tending of machines which are highly repetitive [30].

Under this scope, the motivation for this work comes from several industrial sectors where the human robot collaboration paradigm can potentially be beneficial. Fig. 1 provides several examples where such environments have been implemented to address production challenges in the automotive and white goods sector. Similar applications have been identified in the aeronautics, consumer goods, equipment manufacturing and pharmaceutical industries (see also industry driven research THOMAS (www.thomas-project.eu), SYMBIO-TIC (http://www.symbio-tic.eu/), HUMAN (http://www.humanmanufacturing.eu), etc.). In Fig. 1, the physical setups of such developed assembly cells and their virtual counterparts where the proposed tools may be applied to generate the collaborative cell layouts are shown. The layout varies in terms of the incorporated robots (standard 6DoF arms, overhead dual arm robots etc) as well as product types (size, weight, moving on conveyor or stationary etc.). Thus, the scope can be extended to model any assembly application where partial robotization can be considered. The proposed tool would be particularly valuable to any system integrator that would like to consider the possibility of hybrid production systems in his early conceptual design activities.

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