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Towards shared autonomy for robotic tasks in manufacturing

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Abstract

Recently a new class of industrial robots hit the market that can be potentially used in the same environment as human co-workers (fenceless) if relevant norms are fulfilled. The concept of robots cooperating with humans has gained a lot of interest in the academia, but lacks nowadays applications in both domestic and industrial areas. In this paper, we present a platform for human robot collaboration, which allows building applications of human robot interactions in an intuitive way. Using this platform, the worker is enabled to pursue different levels of shared autonomy between human and robot. Three applications in industrial environment are demonstrated with increasing level of autonomy from coexistence to collaboration. These examples exemplify the usability of such a flexible system in the automation chain and the presented results provide strong evidence of the technological potential in the field.

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Keywords: human-robot cooperation; human-robot interaction, shared autonomy.

1. Introduction

In recent years, the concept of robots cooperating with humans has gained a lot of interest, in both domestic and industrial areas. In industrial environments, the combination of cognitive capabilities of humans with the physical strength and efficiency of the robots/machines can essentially reduce the amount of fixed production costs in

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relation to variable costs. The robot systems are also understood as proper means to address changes in demography and shortage of skilled labor in material goods production. Furthermore, they provide higher flexibility and ensure higher quality of products, which are already nowadays challenging companies. Setting up and operating a system in a fenceless environment requires and being responsive to human interactions requires new sensor capabilities integrated in a human robot system which is in turn embedded in a production system. Human robot interaction is differentiated at different levels with varying degree of shared autonomy as human robot coexistence, cooperation and collaboration.

In this paper, we present a platform called XRob, which allows building models of human robot interactions in an intuitive way. Using this platform, the operator is enabled to pursue different kind of task sharing operation in applications requiring customized patterns of interactions. According to the different kinds of shared autonomy we give examples of how processes can be implemented in industrial settings. The processes addresses key issues in manufacturing such as fast ramp up, zero defect inspection and reducing manual labor in assembly operations. The coexistence scenario describes a robot assistant system focusing on quality control tasks. The mobile platform features a flexible quality inspection system which can be enhanced with a variety of sensors and inherits intuitive configuration capabilities. Working side by side in the same working space describes a scenario of an assembly of automotive combustion engines. Beside rapid reconfiguration of the system, also safety issues have to be taken into consideration. The assembly scenario demonstrates a cooperation scenario where robots carrying out screwing operations beside human attaching parts on the same work piece. The third example shows the collaboration of human robot teams. The intense interaction between human and robot requires a mutual understanding of the task at hand. Specifically, for the robot to assist the human operator for a given task involves understanding the actions performed by the human, interpreting the activity and eventually interacting with the human. This is prerequisite to enable seamless interaction.

Finally, the paper sets the different levels of shared autonomy in comparison and gives remarks on the requirements of successful implementation in industry.

2. State of the Art

In an era of transformation in manufacturing demographics from mass production to mass customization, advances on human-robot interaction in industries has taken many forms. However, the aim of reducing the amount of programming required by an expert using natural modes of communication is still an open topic [1]. In this context, to achieve the goal of easy and quick re-programming by non-experts the task-level programming paradigm is employed.

One of the well-known early works on task-level programming [2] is based on a set of actions, which alters the current world state. They can be perceived as primitive formal descriptions of compliant robot motions and are composed of primitives. These primitives can be defined as simple, atomic movements, that can be combined to form a task [3]. A primitive is typically a sensory input or a single robot motion, described using the Task Frame Formalism (TFF) [4]. In other words, the assembly task is broken down into some form of action primitives the robot can interpret [5]. However, this involves the problem of modeling the world state, and maintaining the model. As a result, when using such primitives the difficulty in modeling a task increases exponentially as the complexity of the task increases. In this paper, we show case our work on building an assembly task with generic recipes. The terms recipe and skill are used analogously in this paper. These recipes (composed of a set of primitives) are abstracted on a higher level and hence form a bridge between complex tasks and the primitives. The idea follows along the idea of high-level abstraction for generalization proposed in [2].

Depending on how these primitives are combined, several approaches are described in literature. An approach using a visual programming tool for defining the flow control to support hierarchies and concurrencies in a state-machine like concept is proposed in [6]. [7] shows an automated task planning and execution system as a sequence of skills and their parameters, based on the desired goal state and the current state from the world model. A robot-programming framework adaptable to variations in the process using knowledge-based components to enhance the robot teaching process is proposed in [8]. For portability across different platforms, components are integrated into a skill-based framework in [9], coupled with a task planning component.