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A Methodology for the Planning and Implementation of Service Robotics in Industrial Work Processes

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Abstract

The gap between capability and practical application of service robotics increases constantly, especially regarding to SMEs. In order to overcome the affiliated obstacles, easily applicable methods supporting users in the planning and implementation of robot solutions need to be developed. Therefore, the proposed methodology determines a useful degree of automation for manual work processes by the help of four main components. A potential customer will be able to join an internet portal. Via this portal, the customer may add data on specific manual work processes, adjacent influencing parameters and additional framework conditions. This data is then forwarded to an associated planning kernel which derives information on different service robot components from a data base. By comparing the requirements regarding the specific manual work process with the different robot characteristics, the planning kernel produces results in two categories. First, the system recommends robot components that can be applied for the specific work process and second, motion plans for the selected service robot system. In order to enhance practical usability and transparency for the customer, the planning kernel is connected to a simulation. Regarding this simulation, the robot components and motions will be automatically visualized to the customer. Consequently, the customer will be able to easily decide on a potential robot implementation in order to support employees and improve the work processes. In practical application, this solution can especially improve the competitiveness of SMEs.

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1. Introduction

Two aspects will have major impact on the development of the German economy in the future. The first one being an increase of the average working population's age because of demographic changes and the second one being an increase of process complexity [1]. When considering these two points, one question arises: How may an older workforce cope with more elaborate working processes and ensure a positive development of the German economy? One possible answer is the support of employees by industrial service robotics. By benefiting from older employees' experience as well as from the performance parameters of service robotics, a high overall productivity will be ensured.

In order to enable further industrial establishment of service robotics, the goal of the project presented here is to automatically evaluate the possible level of automation of currently manual work processes. Therefore, the development of a decision support system is proposed. The idea is to provide users with the means to enter data on manual work processes and on additional criteria influencing the evaluation via an internet portal. This data will be transferred to a planning

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system which determines a useful degree of automation for the manual process and produces two different results. First, suitable robot components that can be used for process automation in the specific manufacturing process and second, motion plans for the specific components. Additionally, a simulation visualizes the recommended components and functions and allows for a swift industrial deployment.

Concerning future fields of operation, industrial assembly is of high importance as the degree of robot utilization is relatively low. For this reason, the project will be described using the example of industrial assembly processes. In this area, the level of automation knowhow in SMEs is often lower compared to larger enterprises. Hence, the potential for improvement by using such a decision support system (DSS) is very high.

2. State of the art

In context of the underlying project, the findings in three established research areas provide the scientific foundation. Ideas for the development of a planning system that is able to process information on manual assembly processes and additional qualitative and quantitative limiting factors can be derived by looking at classic deterministic planning approaches. In order to transfer the information on the work processes into the planning system, a language that provides a standardized description of these processes is needed. A central competence of the planning system is the recommendation of robot components and potential motion sequences. For this purpose, findings in the area of DSS utilized in similar areas of application can be used as a basis.

Classic deterministic planning approaches are based on search methods. These methods try to find ways to modify scientific models in order to reach a specific target state. Therefore, they analyse possible model changes and their specific effects. Usually, the underlying models are complex and the number of possible model changes is very high. As a consequence, search methods cannot examine every single way to adapt a model. Hence, current search methods reduce the complexity of the system or make use of heuristic approaches. Methods reducing the complexity by means of graphs are GRAPHPLAN [2] or Satplan [3]. Current heuristic approaches are often based on the HSP Planner [4]. Very popular methods which are derived from this planner are the Fast Downward approach by Helmert [5], the LGP-Planner [6] and the Fast-Forward Planner [7]. In order to describe planning problems, specifically developed planning languages can be used. Popular examples are STRIPS [8] and PDDL [9].

The standardized description of manual assembly processes is a field of research since the 1920s when the Motion-Time Analysis was developed [10]. Based on that, the MTM (Methods Time Measurement) association provides further developed possibilities for the description of a majority of all manual working processes [11]. Among these different variants, MTM-1 is the basic method which consists of three steps. First, the complete motion sequence which will be analysed is divided into five basic motions. These basic motions are then matched with influencing parameters within the specific process. For example, reaching for an object is a basic motion while the distance is an influencing factor. As a result, time values for the execution of any specific motion can be derived from these two aspects. In this context, it is very important to keep in mind that most manufacturing processes consist of plenty basic motions. As the effort necessary for the correct description of these processes is very high, it only makes sense for standardized processes with little changes in the working procedure. In order to benefit from a process description within highly dynamic processes as well, the MTM association provides different methods which make use of different levels of detail [12]. Methods based on a lower level of detail condense the basic motions. For example, the MTM-UAS method only utilizes one standard motion sequence which consists of the five basic motions. The effort necessary to describe manual processes is substantially lower utilizing only this single element. By this means, the application for dynamic processes also becomes a vital option leading to an overall broad field of application. All in all, the MTM association provides a collection of very flexible methods which consider additional influencing parameters. Within this research project, these are very important preconditions and main reasons why MTM will be utilized.

Research approaches in the field of DSS for the virtual selection of components do not exist. Yet, a variety of scientific literature is available in adjacent areas. DSS are e.g. a current topic in the field of business administration. A good overview is given by Turban [13]. Another application area for DSS is the creation of software systems by composition of standardized software components (Commercial off-the-shelf). The selection of hardware components can be done automatically [14] or interactively [15]. Wanyama [16] offers an overview on DSS in this area. A good case study for the selection of flow meters is given by Seddon [17]. He compares decisions of the DSS with the decisions of a human expert. Pashkevich [18] describes a method for the selection of welding components and robots in the automotive industry based on genetic algorithms. Nguyen [19] developed a framework for the selection of tools based on a CAPP (computer aided process planning) system. In general, DSS are based on multi criteria optimization. A good insight into this topic can be gained by looking at the work of Ehrgott [20]. A central component of the DSS that will be developed in this project is a Virtual Testbed [21-23] that is able to analyse the suitability of potential components. One part of this analysis is the planning of production system configurations. Hausknecht [24] provides information on the structure of expert systems for this purpose.

3. System architecture

The project described here does not only have scientifically oriented claims, but aims also for a high practical usability. Therefore, the sequence in which the system elements will be described is user-oriented. An overview illustrating the operating structure is given in figure 1.

In the first step, robot component manufacturers and potential customers who want to evaluate the automation of