Demand-driven Implementation of Human-Robot-Interaction in Manufacturing with Service Modelling

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Abstract—By combining advantages of humans and robots in the manufacturing process Human-Robot-Interaction (HRI) can solve many problems of today's production industry. Nevertheless, it still lacks industrial applications of this promising solution. The reasons are various and can be seen in uncertainties according to safety and a natural lower technical maturity of new systems. Another reason is the absence of a quantitative analysis of the benefits HRI can provide for the users. An assessment of existing work places as well as a selection and evaluation of potential improvements HRI may provide helps to justify investments. Therefore, a decision-making tool for investments in HRI will enlarge the number of use cases. This paper presents an approach to help producing companies comparing possibilities of HRI by evaluating existing process data.

I. INTRODUCTION

The benefits of Human-Robot-Interaction (HRI) can be evaluated in an economic, ecological and social dimension covering acceptance and ergonomics. All mentioned dimensions combine different aspects. E.g. economy may be influenced by a higher flexibility, more added value, shorter tact time and the needed invest for the HRI system [1, p. 27]. These evaluation criteria of implemented HRI systems help to assess the potential of existing work places in advance. It is necessary to describe and demonstrate validated benefits of HRI according to individual motivation of a company [2].

Another reason for the lack of industrial applications of HRI is uncertainty in the context of safety regulations. Therefore ISO/TS 15066 [3] has been introduced in 2016. It defines allowed collision forces for different body parts. These specifications will help to build confidence for HRI systems in the whole process chain from technology providers, system integrators and end users [4]. According to a shared workspace and the interaction during a performed task different forms of HRI can be distinguished reaching from coexistence to collaboration [5]. Thereby, the requirements for safety technology and the risk depend on the chosen form of interaction. Consequently, the necessary amount of money varies and the return of invest being the most important factor for investments in many companies [6, p. 518] depends on the level of interaction. For a methodology, assessing potentials of HRI a main requirement is flexibility since the developments in HRI are fast and latest trends have to be considered. The multi-layer approach of service modelling defines a meta-model with time-related process steps and an

additional logical structure for the conditions and relations between predefined classes. Thereby, several models can be developed to achieve the overall objective with different methods. The presented approach provides the following benefits:

- Consideration of individual motivation
- Neutral selection and evaluation of work places
- Objective choice for the end user.

II. MULTI-LAYER APPROACH TO SERVICE MODELING

Modelling is a common solution in software development and helps structuring complex problems by defining architecture for a solution [7, p. 581]. The multi-layer approach of service modelling offers a flexible solution by designing a meta-model that defines requirements for different models to be applied in various applications [8], [9]. The context of the different layers is illustrated in Fig. 1.

Fig. 1. Multi-layer approach with correlations (based on [8], [9])

The meta-model consists of a temporary structure for different process steps and a connected logical structure. In UML classes relate to possible attributes and are linked via associations and compositions [10, p.15]. The meta-model of the evaluation and selection of possible work places for HRI is presented in Fig. 2. Thereby, the initial data are the request

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to change of the company and the given process parameters (marked bolted). The challenge is to structure the request and evaluate possible HRI benefits with the given process parameters.

Fig. 2. Meta-model defining requirements for the planned models

Possible methods to address the needed objectives of each process step are shown in Fig. 3. In form of a morphological box the methods can be selected according to the needs and requirements of each user. Companies vary according to their available process data, the possibility to share data with external experts and their needed level of detailed analysis. The morphological box offers a set of possible tools to be chosen according to the individual constraints.

Thereby the structuring of the motivation is carried out first and a plant screening of suitable work places may follow to reduce the expense. The analysis of the production will be carried out according to the individual motivation and the selected work places with existing process data. For selected work places a cost-benefit-matrix or other evaluation methods are applied to compare possible HRI work places. As HRI can be designed in different levels this results in different concepts. Therefore, one work place may appear in the assessment with different HRI concepts.

The analysis of selected work places refers to individual motivation and requirements of the HRI end user. The best-rated work place is recommended to be realized since it provides the suitable benefit for the company. The realization is accomplished by risk sharing between technology providers with expertise in safety assessment, simulation or HRI concepts and integrators.

Fig. 3. Morphological box of suitable methods for each process step

III. FUTURE RESEARCH

To benefit from the presented approach a profile with advantages and requirements should be offered for each

method of the morphological box. Thereby, companies can choose their individual most suitable methods and benefit from others experience. The profiles should provide an overview of necessary process data, provided benefits and level of detail for each method to simplify the choice. For an academic validation of the whole presented methodology a case study with at least three producing companies will be implemented.

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