Data Acquisition and Classification of Best Practices for the Configuration of Robot Applications

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Abstract. Despite the far-reaching technological developments in the field of robotics (e.g. lightweight robots), the degree of implementation of innovative solutions in industrial practice is still comparatively low. This applies in particular to inexperienced users from small and medium-sized companies (SME). To facilitate the transfer of robot applications into practice, an internet-based configurator has been developed within the ROBOTOP research project. The configurator comprises planning functions along the whole engineering process. With regard to these functions, industrially implemented best practices are a main focus within the concept phase. Furthermore, they form a foundation for all further planning steps. In this context, the term ‘best practice’ refers to successfully implemented industrial applications. The acquisition, structuring and integration of these best practices into the web platform constitute the core of this paper. In order to highlight the emerging considerable benefits for industrial end-users, the digital implementation of best practices within the framework of the ROBOTOP internet platform is presented in the last step. The continuous use of digital planning platforms can ultimately pave the way for a significant increase in the degree of implementation of innovative robot applications.

Keywords: Best practices, data acquisition, classification, robot configuration, Industry 4.0

1 Introduction

In the field of robotics, extensive research results have emerged in recent years. Despite the considerable potential of new technical achievements, e.g. lightweight robots, these systems often have not yet found their way into industrial practice. One reason for this is that the planning and configuration process requires industrial users to have extensive prior knowledge [1].

In order to counteract this problem, a modular and open internet platform with engineering functions along all phases of automation planning is developed in the

ROBOTOP research project. The aim is to use industrially implemented best practices as a foundation for a need-based planning process [2, 3]. On the basis of this planning process, inexperienced industrial end-users are introduced to the field of robotics. In this way, the mass market for industrial and lightweight robots will be opened up in the future [4, 5].

2 Planning Approaches

In order to automate a production process by means of industrial or lightweight robots, various planning steps are necessary. In this context, numerous planning approaches were developed within the last years. These can be divided into application-neutral approaches [6], assembly-related methods [7] and automation-related systems [8].

Application-neutral planning methods are characterized by a more general description of the planning contents which makes them suitable for a wide range of applications. The REFA planning method was developed in the form of a guideline and can be used by industrial users for work design in general [9]. The method is suitable for various application scenarios that can relate to production as well as to the areas of service and administration. However, the main weakness of application-neutral methods lies in the lack of a connection to the field of robotics, e.g. configuration of robot system and safety requirements.

Assembly-related approaches are particularly suitable for detailed planning of work and assembly systems. In this context, Hartel and Lotter [10] developed a method for the planning of production lines from the assembly area. A special feature of this method is its high flexibility, as the individual product and production parameters of the examined application scenario can be varied, e.g. product design, product complexity and sales volume. Another example is the reference planning process [11] which can be used to plan various industrial scenarios, such as production, logistics, assembly or layout planning. Moreover, the Bosch planning guideline is based on lean production and scalable automation concepts and supports industrial users in all phases of production planning [12]. Overall, the assembly-related approaches have many advantages. However, the area of robot-based automation is not sufficiently considered.

Automation-related approaches serve to design work sequences that are carried out by humans or robot systems. A large part of these procedures is based on a skill-oriented allocation of work tasks. Here, the consideration of different levels of automation [13, 14], concept-based assembly planning [15–17] and MABA-MABA diagrams [8, 18] should be mentioned. A central criticism of these approaches is that they only consider a very specific part of the overall planning process and, for example, do not provide approaches for detailed and implementation planning.

In total, there is a large number of different planning approaches available which, however, have specific disadvantages with regard to the underlying planning task. In particular, the usability for industrial users without specific prior knowledge in the field of robotics is very limited. On this basis, the ROBOTOP configuration process for the implementation of robot applications has been developed. Here, inexperienced end-

users benefit from digital assistance tools and best practice solutions so that SMEs in particular gain access to robotics.

3 Internet-based Configuration Process

The aim of the internet-based configuration process is to facilitate planning procedures for both robot suppliers and customers and thus link both groups together directly. As indicated in Fig. 1, the ROBOTOP platform offers extensive assistance functions in all phases of automation planning.

Fig. 1. ROBOTOP configuration process

In the course of an initial selection of best practices, potential end-users first have the opportunity to describe their individual application scenarios (e. g. manual workstations) using a structured and user-friendly questionnaire. Suitable best practices are derived in an automated selection process.

The best practices serve as an initial concept proposal for the end-user and as a basis for the following individual configuration process. In this course, suitable robot systems, peripheral components and gripping systems can be freely combined with each other, whereby the compatibility of the individual components is guaranteed at all times.

To increase user-friendliness, the assembled systems can be directly transferred to an online 3D simulation. Users can make an initial assessment of the technical

feasibility of the assembled solution for their specific application scenarios. Depending on the result, it is then possible to go through upstream process steps again to improve the planning results. Alternatively, potential service providers may be contacted directly to obtain quotations. However, in order to achieve such high quality results in later planning phases (e. g. individual configuration, online 3D simulation), the selection of suitable best practices at the beginning is indispensable.

3.1 Fields of Application for Best Practice Acquisition

To ensure that best practices can be used for as many planning scenarios as possible, they should represent a broad cross-section of industrial applications. Therefore, frequently occurring industrial tasks were determined and categorized.

Within the framework of a literature research, the results of various studies on the frequency of specific types of robot applications in industry were consolidated [19]. In addition, concepts and guidelines for the description of work tasks for robot systems were examined [20, 21]. The result was a heterogeneous overview of different robot operations.

This overview was revised by experts from industry and research in various surveys. As a result, nine elementary robot applications could be identified. As indicated in Fig. 2, these could be divided into four higher-level categories.

Fig. 2. Best practice classification

The common feature of machine loading / unloading, pick and place activities as well as positioning tasks is that individual objects are picked up, moved and placed in a different location. For this reason, the operations are assigned to the "handling" category. Furthermore, composing an object places higher demands on a potential robot system, since one object has to be inserted specifically into another. Similar to the screwing of objects, these activities increasingly occur in industrial assembly. For this reason, assembly and screwing are assigned to this category. Further typical tasks of a robot system are scanning of features and quality inspection. Since optical sensor systems are often used for this purpose, these activities are assigned to the "optical inspection" category. In addition to the handling and inspection of components, robots are increasingly used in industry for coating and machining processes (in particular cutting). These activities have been classified in the "machining" category.

Overall, robot systems are used in industry for a variety of other application scenarios (e. g. welding). However, a central requirement of the web platform is to comprise representative best practices that allow inexperienced users in SME an easy introduction to the field of robotics. This can be well ensured by the described best practices classification.

3.2 Best Practice Database

Based on the developed structure, industrial application partners within and outside the ROBOTOP research network were approached for the collection of best practices. This includes SME as well as large corporations in the automotive industry, machine and plant construction, packaging industry and air conditioning technology. This way, best practices data was collected for all four categories. However, an above-average number of handling tasks occurred. These are scenarios that can be automated easily and mainly without the aid of complex sensor technology. This underlines the current industrial trend that lightweight robots are used increasingly for simple applications. In addition, there is the significant advantage that these applications offer an ideal planning guideline for inexperienced users from SME.

In order to select suitable best practices in the first step of the configuration process, it is necessary to compare the requirements of the examined user scenario with the properties of the best practices. Therefore, the best practices are described thoroughly on the basis of defined characteristics. This was ensured by the development of a uniform data sheet.

The best practice attributes include metadata of the individual components such as robots, grippers, tools and conveyors, types of material feeding and safety-related equipment. Moreover, the IP protection class, component properties, control systems as well as the upstream and downstream process are taken into account. On the basis of the generated data, ROBOTOP can provide industry-independent best practice solutions for various application scenarios. In this way, the project can significantly promote knowledge transfer to SME.

3.3 Selection of Best Practices

For the selection of best practices as a planning foundation, some information on the specific investigation scenario, e. g. manual assembly workstation, is required. This data is collected using a structured questionnaire. This includes questions relating to the work task to be examined and questions relating to the handling objects.

The required information on the work task mainly refers to the four categories presented in this paper (i.e. handling, assembly, optical inspection, machining). This allows eliminating unsuitable best practices that do not correspond to the field of investigation.

As a next step, information on the handling objects is required since these have significant influence on the automation capability [22]. The queried object data includes the geometric body (ellipsoid, cuboid and cylinder) as well as information on the maximum dimensions. Furthermore, data regarding component stiffness, material properties and component mass is collected. Based on this product data, further improper best practices can be eliminated. For example, the weight of the handling objects has significant influence on the payload and thus on the size and type of the entire robot system. If the weight range of the application scenario does not correspond to the best practice, the best practice is evaluated as unsuitable and excluded from the configuration process. In this way, it is possible to carry out a meaningful pre-selection and to propose suitable best practices to industrial users.

4 Application

The planning logic as well as the best practice solutions were integrated into the ROBOTOP internet platform as part of a 3D demonstrator. The digital representation contains all CAD models necessary for the visualization of the best practices. This includes material feeding components, the representation of products, load carriers and conveyor elements, the robot system with its gripper or tool components, safety engineering as well as the switch cabinet. By means of this level of detail, the ROBOTOP configurator is provided with sufficient information about the correct functionality and visualization of the production process.

Based on the requirements analysis, suitable best practices are pre-selected for the user in the first step. As it can be seen in Fig. 3, industrial end-users can view suitable best practices in a 3D environment and compare the essential properties with each other. For this reason, the configuration interface displays the corresponding attributes. This includes information on the kinematics used, the end effector and the estimated price. Furthermore, the platform includes a rendering of the scene to get an initial overview of the components used. This allows industrial users to select individually one of these suitable best practices for further configuration steps.

Furthermore, the user has the possibility to customize his robot application in the configuration mode. Various components such as workpieces, feeds or safety features are available for selection. Using the component-positioning menu, suitable elements can be selected and added to the overall system.

	Best Practice Solution ↑	Automized Operation	Robot	End Effector
BP 01: Loading a machine with sheets	Load Machine	UR-5	suction gripper (in-house production)
BP 02: Loading a packaging machine	Pick And Place	UR-5	suction gripper (in-house production)
BP 03: Screw connection to a loudspeaker module	Screw	UR-3	screwdriver (in-house production)
BP 04: Exchange of holding mandrels	Load Machine	RS010N	PGN-Plus
BP 05: Loading a grinding machine	Load Machine	Sawyer	Sawyer standard gripper
BP 09: Screw connection to power unit	Screw	LBR iiwa - 7 R800	KUKA LBR-AB-Class screwdriver
BP 21: Joining a brush holder	Assembly	YuMi - IRB 14000	IRB 14000 - gripper
BP 22: Assembly and pressing	Pick And Place	YuMi - IRB 14000	suction gripper (in-house production)

Fig. 3. Preselection of best practices on the ROBOTOP web platform

This includes working tables, conveyors, robots and end effectors. In this way, the user can select between various manufacturers and choose the right object type. Alignment can take place within all six degrees of spatial freedom. To ensure compatibility between, the configurator displays only suitable solutions (see Fig. 4).

Fig. 4. Individual configuration process based on a suitable best practice

As can be seen in Figure 5, it is possible to store realistic data for each added object. In this case, the configurator menu shows the parameters for a new workpiece. At this, information concerning basic geometry, dimensions, weight and material can be edited. Due to the 3D environment and clearly defined input queries, no in-depth knowledge of robotics is required, so that almost every industrial end-user can benefit from the web platform.

The screenshot shows a web configurator interface with the following sections:

- Application Area**: A dropdown menu with a downward arrow.
- Workpiece**: A dropdown menu with an upward arrow.
- What is the shape of your workpiece?**: A question with a help icon. Below it are five buttons:
 - Cuboid**: Selected, indicated by a green checkmark icon.
 - Plate**: Represented by a blue plate icon.
 - Ellipsoid**: Represented by a blue ellipsoid icon.
 - Cylinder**: Represented by a blue cylinder icon.
 - CAD**: Represented by a blue square with an upward arrow and the text "LOAD FILE".
- What are the dimensions of your workpiece?**: A question with a help icon. Below it are three input fields:
 - Length:** 50 mm
 - Width:** 100 mm
 - Height:** 100 mm
- What is the weight of the workpiece?**: A question with a help icon. Below it is an input field:
 - Weight:** 500 g
- What is the material of the workpiece?**: A question with a help icon. Below it is a dropdown menu:
 - Please select...**
 - Metal (magnetic)**: The selected material.

Fig. 5. Editing of realistic workpiece data

5 Conclusion and outlook

Industrial robot applications must meet significant technical requirements to ensure high availability, quality and safety. In many cases, this results in highly complex applications. The successful planning of these robot systems requires a correspondingly

high level of specialist knowledge, a wealth of experience and extensive knowledge of the standardization situation. Especially for SME, this represents an entry barrier to the use of industrial robot applications.

This problem was a main motivation for the ROBOTOP research project. The web platform enables industrial end-users to go through the entire configuration process from initial concept planning to preparation for implementation. By using industrial best practices as a planning foundation, users gain a practical insight into the field of robotics. In addition, the extensive assistance functionalities of the platform and the detailed 3D representation enable even inexperienced users to run through the entire planning process without any additional help.

Overall, powerful web platforms mapping the complete engineering process are a key technology of the future. These can ultimately pave the way for a significant increase in the degree of implementation of innovative robot applications.

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