Taneli Lohi*, Samuli Soutukorva and Tapio Heikkilä

Programming of Skill-based Robots

Abstract: Manufacturing is facing constantly changing market demands, with faster innovation cycles resulting in growing agility and flexibility requirements. Industry 4.0 has been transforming the manufacturing world towards digital automation and the importance of software has increased drastically. Easy and fast task programming and execution in robot-sensor systems become a prerequisite for agile and flexible automation and in this paper, we propose such a system. Our solution relies on a robot skill library, which provides the user with high-level and parametrized operations, i.e., robot skills, for task programming and execution. Programming actions result in a control recipe in a neutral product context and is based on use of product CAD models. Practical tests are also reported to show the feasibility of our approach.

Keywords: robot programming, robot skill, computer vision

***Corresponding Author: Taneli Lohi:** VTT Technical Research Centre of Finland, E-mail: taneli.lohi@vtt.fi

Samuli Soutukorva: VTT Technical Research Centre of Finland, E-mail: samuli.soutukorva@vtt.fi

Tapio Heikkilä: VTT Technical Research Centre of Finland, E-mail: tapio.heikkila@vtt.fi

1 Introduction

Automation in agile and very flexible manufacturing, where lot sizes go at the extreme cases down to one is very demanding, because the set-up and execution of new tasks should be nearly instant. This implies reduced integration effort and easy reuse of available devices and software on the production lines. The devices must offer a uniform interface to fulfil flexibility requirements and new devices and components of a production line must be integrated fast and easy, independent of the component's manufacturer [1]. Software plays a key role, and the transition to small batches implies robot software structures and control architectures that can provide the basis for the required flexibility [2].

Our approach to solve the challenges of agile and flexible robot automation is to introduce a system for easy programming and execution of robot tasks. Our solution relies on an executable robot skill library, which provides the user with high level parametrized robot skills. Programming is based on use of product CAD models in a neutral format and is carried out using a planning and programming software in the product context, focusing on what operations, i.e., robot skills, need to be carried out to accomplish the required changes in the relations and properties of parts. We have developed a planning and programming software system as well as a robot skill library, with which task sequences and all detailed parameters can be easily programmed into a control recipe. The control recipe is interpreted by the control software and skills and operations are allocated to available resources and executed in a robot cell.

Our main contribution and novelty is in providing the method and software implementation for easy task planning and programming in the product context based on CAD models – as well as in the modelling of synchronization of skills.

2 Hierarchical control – modelling tasks, skills and primitives

Our control architecture follows the principles of the common three-layer architecture [3]. We have layers for tasks, skills, and primitive operations. Parametrized skills and primitives are specified, designed, implemented, and tested and realized as a reusable component library, relying on which, varying tasks can be planned and programmed. Tasks are formulated as sequences of skills, which further on are decomposed according to the behaviour patterns of the skills and primitives. In principle, tasks have no predefined control structures, but are always composed as a sequence of skills, specified by human operator or programmer.

Skills and primitives have always their predefined sequence control structures, including synchronization of skills and primitives. Planning a task is done by the user by selecting skills one by one from a list of skills and setting a target object for each skill. Further on, the required parameters for skills are derived from the CAD models of the parts connected to the skill. A complete task plan with the skill sequence and related skill parameters is finally composed into a control recipe, which is forwarded to the robot control system. The robot control system merges configuration data of the robot system to finalize the skill and primitive parameters.

Each control sequence of a skill or a primitive operation is implemented as a control program component: as an executable, as a module in an executable or as a module in an interpreted control script. Task level control is implemented with an interpreter in the python language, which parses the control recipe and triggers skill controls in the order specified in the control recipe. The control recipe is implemented as a JSON file, which is passed from the planning software to the runtime environment of the task control. Robot cell configuration data is implemented currently embedded in the configuration files of the HW and SW components, or embedded, as global variables in the interpreter programs

3 Planning and programming system for tasks and skills

A CAD based programming system has been developed using the geometric engine of the OpenCascade Technology [4]. The operator creates a task by selecting predefined skills from list and adding them to the skill sequence. Each skill is connected to one or more target object to be manipulated during skill execution. Geometric features of the target object are used to derive parameters for each skill.

Currently available skills that are supported by the task planning system, are Pick, Place, Localize object, Scan, Pick localized, Place localized and Scan localized. The skills are written to a task recipe, that contains the skills in execution order and the needed parameters for executing each skill.

4 Experimental system and testing

The task programming and control methods were implemented in our laboratory test facilities. The CAD-based programming SW was implemented as a C++ executable. Task and skill controllers are implemented in the python language and skill controls are using VTT's 3D computer vision SW and 3D cameras. ROS Topic and Services based interface is used to communicate with computer vision SW and a robot controller. The robot controller is implemented in the used robot's programming language (KRL). Experimental system and skill models are presented in a more comprehensive way in [5].

An assembly task was created using a CAD model of the assembly by sequencing skills and attaching related parts to the skills interactively (figure 1, left). The skill sequence was written to STEP model. The skill sequence was read from the model and features that are used to generate parameters for each skill are selected from CAD model of the part (figure 1, right). Control recipes for the task was generated.

The assembly task was executed using the task control, with KUKA Agilus robot equipped with Schmalz suction gripper, and 3D computer vision system with Zivid 2 3D camera. (Figure 2)

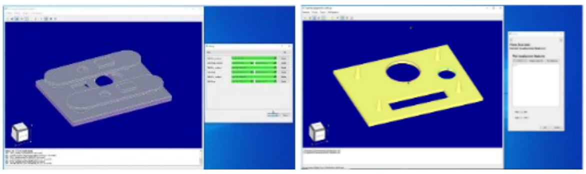

Figure 1. Creating a skill sequence and selecting features for skill parameter generation

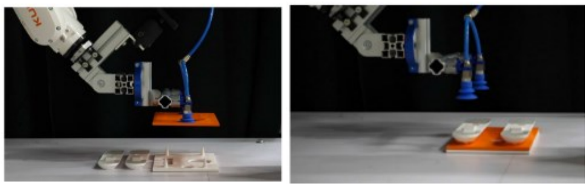

Figure 2. Execution of an assembly task

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