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How to deploy a wire with a robotic platform: learning from human visual demonstrations

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Abstract

In this paper, we address the problem of deploying a wire along a specific path selected by an unskilled user. The robot has to learn the selected path and pass a wire through the peg table by using the same tool. The main contribution regards the hybrid use of Cartesian positions provided by a learning procedure and joint positions obtained by inverse kinematics and motion planning. Some constraints are introduced to deal with non-rigid material without breaks or knots. We took into account a series of metrics to evaluate the robot learning capabilities, all of them over performed the targets.

Keywords: Robot learning, Industry 4.0, Manipulators, Inverse Kinematics, Programming by demonstration

1. Introduction

European industry needs new, innovative ideas and technologies in order to be globally competitive. The advent of Industry 4.0 set a new standard in terms of workflow and customization, and the companies need to be updated to these standards [1]. Agility is a key characteristic for industrial systems and the time needed for introducing a new article should be minimized. Production needs the flexibility to adapt to recurring changes and robotics is a major

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resource in obtaining this goal. Traditionally, industries are more reluctant in trying avant-garde solutions, while the academic world is open to experimentation. EuRoC (European Robotic Challenges)[2] goal is to fill this gap, opening a collaboration between industry and academic world in order to solve industry relevant open problems in a new and innovative way thanks to advances in the robotic field. The final objective is the technologic advancement for the industries to be able to bring them closer to the Industry 4.0 concept.

A key factor for the Industry 4.0 upgrade is the use of robots [3]. Nowadays, manipulators are employed for supply chains in which the same task should be accomplished several times in a repetitive manner. Tasks are programmed and encoded in the robot by experts usually coming from external firms and not daily available in factory. Therefore, robot programs are difficult to modify and even a minimal change could take a long time. Such time spending workflow is not adapt to the highly customized items commonly produced by Small and Medium Enterprises (SMEs) to satisfy a limited number of customers. Furthermore, tasks carried out by robots are usually very complex and difficult to program, even by an expert. Therefore, the human operator knows how to perform a task, but he has not programming skills for programming the robot, since this is a very difficult task also for a skilled robot-programmer. Moreover, the tasks is often risky for a human since it involves the manipulation of heavy parts or repetitive actions. Nevertheless, in the majority of the cases, human operators can understood easily how to perform the task, even in complex situations. A useful solution could be obtained if the operator would be able to teach the robot how to perform a certain task, guiding the robot or showing himself what to do by using a robot learning by demonstration paradigm [4]. Many examples in the literature show the useful aspects of applying a robot learning by demonstration paradigm [5]. Up to now, several research groups have developed different paradigms and techniques, but only a limited number of attempts have been exploited in real industrial environments. Myers et al. [6] wanted to automatically insert a PC card into a backplane slot on the motherboard, treating forces/moments as the sensed inputs and robot velocities as the control outputs. Baroglio et al. [7] believe that robot ability to gain profit from its experiences is crucial for fully exploiting its potential. They analyzed several approaches and tested them in a classical industry-like problem: insert a peg into a hole. The task was performed while recovering from error situations, in which, for instance, the peg is stuck midway because of a wrong inclination. Neto et al. [8] presented a way to program a robot showing it what to do by using gestures and speech. The gestures are extracted from a motion sensor, namely a Wii remote controller. The Japanese company Fanuc is developing robots that use reinforcement learning to train themselves [9]. Fanuc's robot learns how to pick up objects while capturing video footage of the process. The new knowledge is used to refine a deep learning model that controls robot actions. It has been proved that after about eight hours, the robot reaches up to 90% accuracy or above, almost the same as if it was programmed by an expert. With respect to previous works, we introduce two main contributions to the state of the art. The first is introducing in an industrial-like environment the use of a Robot Learning framework trained by means of visual information collected with no need for markers or special tools. The second is making Robot Learning and Inverse Kinematics work alongside in order to benefit from both methods.

1.1. EuRoC challenge

EuRoC project has been proposed in 2014 and it is accurately described in [2]. It consists of three challenges:

- Reconfigurable Interactive Manufacturing Cell;
- Shop Floor Logistics and Manipulation;
- Plant Servicing and Inspection.

The project lasts four years and it consists of a series of increasing difficult stages.

For the Reconfigurable Interactive Manufacturing Cell challenge, five teams have been funded to carry out their projects. In a first phase the objectives were common: all the teams had to perform the same industry relevant task, i.e. automatic assembly a car door module [10]. During next phases each team had to propose and carry out its own project in order to address and solve a need of one or more end users.

Our team's (ITRXCell) end user is ICPE, a Romanian factory producing electrical motors. They need a solution for the development of an automatic electric motor coil winding and assembling. This goal will be gradually reached passing through several demonstrative phases as is shown in Fig. 1. The task complexity will increase from phase to phase, until reaching the desired goal in the last phase. This final stage will test the procedure directly in ICPE facility in a realistic production environment.