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IRoSim: Industrial Robotics Simulation Design Planning and Optimization platform based on CAD and knowledgeware technologies

Khelifa Baizid [a], Saša Ćuković [b,*], Jamshed Iqbal [c], Ali Yousnadj [d], Ryad Chellali [e], Amal Meddahi [f], Goran Devedžić [b], Ionut Ghionea [g]

[a] Mines-Telecom Institute, Mines Douai, France
[b] University of Kragujevac, Kragujevac, Serbia
[c] National University of Computer and Emerging Sciences, Pakistan
[d] Advanced Technology Development Center, Algeria
[e] Nanjing Robotics Institute, China
[f] University of Cassino and Southern Lazio, Italy
[g] University Politehnica of Bucharest, Bucharest, Romania

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ABSTRACT

This paper presents Industrial Robotics Simulation Design Planning and Optimization platform named IRoSim, which is based on SolidWorks Application Programming Interface (API) to offer an intuitive and convertible environment for designing and simulating robotized tasks. The core idea is to integrate features of mechanical CAD and robotics CAD into the same platform to facilitate the development process through the designed Graphical User Interface (GUI) which permits user friendly interaction. The platform includes various 3D models that are essential for developing any robotized task and offers possibility to integrate new models in simulation. Robotic manipulator library is one such example which contains several types of serial arms with different combinations of revolute and prismatic joints. The platform provides most important steps such as defining the task, CAD learning of the end-effector's trajectory, checking the manipulator's reachability to perform a task, simulating the motion and finally validating the manipulator's trajectory to avoid possible collisions. To demonstrate the efficiency of the proposed approach, two frequent and important tasks (spot welding and painting) using a 6-Degree Of Freedom (DOF) industrial robotic manipulator have been considered. The output of the proposed strategy provides collision-free trajectory of the manipulator's motion which can be directly mapped to a real site. Moreover, the approach permits addressing the problems related with the real implementation of robotized tasks.

1. Introduction

The need of robotic manipulators in industrial sector has raised requirements related to the development of robotized tasks. These requirements take place throughout the development phases of the task. Recent advancements in industrial automation have stipulated the need to simulate and control industrial robotized tasks in a more systematic and efficient way [1]. Moreover, developing and programming robotized task in the conventional manner such as using teaching pendant is a cumbersome and time consuming task in general, requiring highly expert operators [2]. This may be a critical constraint for many small and some medium-sized manufacturing companies in setting-up robotic manipulators in their facilities [3]. Even, to date, many industrial manipulators are still designed based on the conventional teaching process. Thus, novel, advanced and more intuitive techniques to develop and program the robotized tasks are required [4–7]. This has motivated engineers to develop tools that help users to carry out robotic tasks, which may require automatic path planning and determination of collision-free path [8]. Additionally, the simulation tools offer potential benefits in terms of reduction in time consumption and ease in the whole process of development of robotized task [6]. The last two decades witnessed Off-Line Programming (OLP) for Computer Aided Design (CAD) learning trajectory through teach pendant [9,10,4]. A possible combination of CAD and knowledgeware methodologies to program manipulators may lead to advances in versatility and autonomy of the modern industrial plants. Thus, industrial product design and robot manipulators programming can be integrated seamlessly [11]. The addition of CAD tools in manufacturing robotic processes [8] has set new trends in the modern industry. Currently robotic systems employ

* Corresponding author.

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intensive use of CAD and embedded knowledge to design the robot mechanism and to simulate the manipulators' movements [11]. However, many of these systems do not rely on standard CAD packages like SolidWorks and CATIA and provide additional packages and modules (mostly not free of cost) for robotic task development. This presents additional difficulties for users to model and to export their 3D models to these standard softwares for simulating a given task. For instance, iteration involving traversal to previous steps is often needed to resolve issues related to the design and development of robotized tasks. Thus integration of a standard CAD robotic system with a CAD software offers several benefits in terms of simplicity in usage and permits users to intuitively interact with a manipulator and its environment. In this perspective, many CAD-guided robot trajectory applications were discussed in [12–14]. For instance, authors in [12] developed a process of manipulator's trajectory generation on a surface based on the 3D CAD model. Our objective in the present approach is to provide an easier process to define a robotized task integrated into a 3D CAD system.

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In this paper, we present a novel platform named Industrial Robotics Simulation design, planning and optimization (IRoSim) that has been realized to assist users working on industrial robotized tasks. As shown in Fig. 1, the system offers users to simulate several steps to fulfill the desired objectives. IRoSim is integrate-able with SolidWorks and can easily be upgraded to future versions. Unlike programming packages [3,2], IRoSim provides several features such as 3D design of the robotic manipulator, definition of the task to be accomplished, accessibility verification, optimization of the task time execution [15], graphical simulation, detection of the eventual collisions and generation of a collision-free trajectory to be directly mapped to the real cell. The objective of this work is to simplify and consolidate all the required stages to develop a robotized industrial task from scratch into the single CAD system. Based on IRoSim, users with a basic knowledge of robotics are able to generate the motion of an industrial manipulator. In order to show the effectiveness of the proposed platform, we implemented two different robotized tasks which are spot welding and painting using a 6-Degree Of Freedom (DOF) robotic manipulator.

This paper is organized as follow: Section 2 presents a generic view of the proposed package while Section 3 addresses with the challenge of accessibility verification. Section 4 gives details of algorithms for placement and orientation zones that are used in the optimization procedure. Section 5 deals with the optimization of the task while Section 6 presents two frequent industrial robotized tasks. Finally Section 7 comments on conclusions.

2. CAD based approach

CAD model databases such as SolidWorks API [16,17] have been widely investigated to define and simulate a manipulator's trajectory in various industrial applications [2,12]. SolidWorks API last offers the feature to calculate the task parameters based on a virtual 3D model of the real robotic cell. Moreover, modifications and redefinition of these parameters are easily possible with a user-friendly integration with SolidWorks. We used a Product Lifecycle Management (PLM) software SolidWorks to develop series of steps that allow user for define simulate and validate a given industrial task. Fig. 1 presents the main blocks of the proposed platform that allows engineers to design, plan and optimize the industrial tasks in the same environment, without the need to export all models from the design environment to the simulation environment. Important steps rebelled in Fig. 1 listed below:

1. Task definition based on knowledge of the real cell.
2. CAD learning based on the virtual 3D model.
3. Accessibility verification of the task and calculations of placement and orientation zones.
4. Time optimization of the task.
5. Graphical simulation and validation of the task.

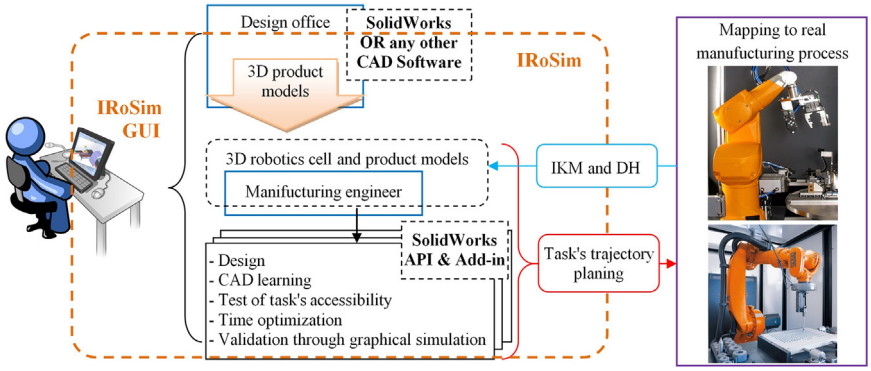

Fig. 1. IRoSim offline-CAD programming schema.